National Park Service
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Natural Resource Stewardship and Science

Nearshore Marine Vital Signs Monitoring in the Southwest Alaska Network of National Parks

2011

Natural Resource Technical Report NPS/SWAN/NRTR—2011/719

ON THE COVER
Otter Cove, KEFJ
Photograph by: Gery Cox, KEFJ volunteer

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Abstract

In 2011, we successfully completed another year of field sampling for the Southwest Alaska Network's (SWAN) Nearshore Vital Signs monitoring program in accordance with standard operating procedures set forth for the six vital signs: marine intertidal invertebrates, kelp and seagrass, marine water chemistry and quality, marine birds, black oystercatcher, and sea otter.

Summer sampling in 2011 represented the fifth year of data collection at Kenai Fjords National Park (KEFJ) for the vital signs: intertidal invertebrates, kelps and seagrasses, water chemistry and quality, marine bird surveys, black oystercatcher diet and productivity, and sea otter diet. No modifications were made to the rocky intertidal sampling protocol from previous years and the protocol and SOPs have been finalized. Hobo water temperature sensors are currently deployed at five rocky intertidal sites in KEFJ. In addition, salinity loggers are co-located at all rocky intertidal sites at KEFJ. We implemented a fourth year of mussel bed and eelgrass bed sampling and a final SOP for sampling mussel beds is near completion and will be sent out for peer review in 2013. Modifications for eelgrass bed monitoring are being made and a new draft SOP will be sent for review in the spring of 2013.

KATM was not sampled in 2011, but will be again in 2012. 2011 represented the third year of sampling in Prince William Sound (PWS). Data from PWS rocky intertidal is presented here in anticipation that all three areas (KATM, KEFJ and PWS) will continue to be sampled and analyzed together in order to provide a larger spatial context to the analyses.

Marine bird surveys in KEFJ and KATM will continue with little modification in 2012. For marine bird surveys, we recommend that the survey effort continue until further analysis can be completed. The existing SOP for marine bird surveys is final.

Black oystercatcher abundance, nest density, productivity and diet data should continue to be collected with little revision. Sampling at the current intensity should allow us to detect trends in changes of nest density, productivity and diet (especially prey size) of the black oystercatcher. The SOP for black oystercatcher monitoring is also final.

An aerial survey of sea otter abundance was completed in KEFJ during June 2010 with results of the survey available at the Southwest Alaska Network web pages. (http://science.nature.nps.gov/im/units/swan/Libraries/Reports/ColettiH_2011_KEFJ_SeotAerial2010Report_2167598.pdf)

Sea otter foraging data was collected in KEFJ in 2011. Mussels (*Mytilus trossulus*) dominated sea otter diets across all years of data collection (2007-2011), comprising 61% of the diet. Clams were the second most prominent prey item, comprising 25% of the diet. Otherwise, chitons, crabs, octopus, snails, sea stars, sea urchins, and other prey each comprised less than 10% of the of prey recovered. Annually there has been little observed change in the predominant prey category at either KATM or KEFJ. A sea otter forage database has been completed. Database completion will ease data entry both in the field and office as well as optimize data analysis. Carcass collection continues in KEFJ, although to date we have not recovered enough carcasses from KEFJ to employ age-specific mortality analyses.

In 2011, the protocol narrative was finalized through an external peer review process. http://science.nature.nps.gov/im/units/swan/Libraries/Reports/DeanT_2011_SWAN_NearshoreMarineProtocolNarrative_20110202_nrss.pdf

In the spring of 2013 we will finalize data entry and data management procedures for the rocky intertidal SOP. We will continue to sample nearshore vital signs at KEFJ and KATM in 2012.

Acknowledgments

The National Park Service, SWAN, KATM, KEFJ, LACL and the USGS Alaska Science Center supported this work. We would like to recognize the exceptional cooperation by the staff of KATM, KEFJ and SWAN, in particular; Laura Phillips and Mark Kansteiner (KEFJ) and Carissa Turner (KATM) for their field assistance in 2011. This work could not have been completed without the field assistance of Allan Fukuyama (contractor) and a great volunteer, Gery Cox. Thank you to Tim Shepherd (SWAN) and Brenda Ballachey for their thoughtful reviews.

We also want to extend a special ‘thank you’ to Jamie Thompton for his skilled operation of the R/V Serac in KEFJ.

Intertidal Invertebrates and Algae

Introduction

Intertidal invertebrate and algal communities provide an important source of production; are an important conduit of energy, nutrients, and pollutants between terrestrial and marine environments; provide resources for subsistence, sport, and commercial harvests; and are important for recreational activities such as wildlife viewing and fishing. The intertidal is particularly susceptible to human disturbance including oil spills; trampling by recreational visitors; harvesting activities; pollutants from terrestrial, airborne and marine sources; and shoreline development. Changes in the structure of the intertidal community serve as valuable indicators of disturbance, both natural (e.g. Dayton 1971, Sousa 1979) and human induced (Barry et al. 1995, Lewis 1996, Keough and Quinn 1998, Jamieson et al. 1998, Shiel and Taylor 1999, Sagarin et al. 1999, Peterson 2001, and Peterson et al. 2003).

Intertidal invertebrates and algae (including intertidal kelps) were sampled annually at KATM beginning in 2006, and at KEFJ beginning in 2008. PWS sampling began in 2007 and then again from 2010-2011. Sampling of intertidal invertebrates and algae at these sites is designed to detect changes in these communities over time as part of the SWAN Vital Signs program. The specific objectives of this sampling on rocky shores are to assess changes in: 1) the relative abundance of algae, sessile invertebrates, and motile invertebrates in the intertidal zone, 2) the diversity of algae and invertebrates, 3) the size distribution of limpets (*Lottia persona*) and mussels (*Mytilus trossulus*), 4) the concentration of contaminants in mussel tissue, and 5) temperature (either sea or air depending on tidal stage). In this section, we present results of sampling conducted in 2006-2011. The metrics to be examined are: 1) abundance estimates for dominant taxa of sessile invertebrates and algae, and the size distribution of the limpet *Lottia persona*.

Methods

Sampling was conducted at five sites in sheltered rocky habitats within KATM, KEFJ and PWS. Descriptions of the study sites and methods used to sample intertidal algae and invertebrates are available in Dean and Bodkin (2011b). Sites were chosen using a GRTS procedure (Stevens and Olsen, 2004) that provided a spatially balanced yet random selection of sites. The following is a general description of the methods employed. Sampling of abundance and species composition for algae and invertebrates was conducted along two 50 m linear transects at each site. The percent cover of algae and sessile invertebrates was estimated within 12 evenly spaced ¼ m^2 quadrats placed along transects that ran parallel to the shoreline and originated at permanent markers placed at 0.5 m and 1.5 m tidal elevations, respectively. Quadrats were placed at random start points and at equally spaced intervals thereafter. In addition, a minimum of 119 individual limpets (*Lottia persona*) were measured at each site for estimation of size distributions.

The analyses presented here focus on estimates of abundance of dominant taxa at each tidal elevation, and on size distributions of limpets. Means and 95% confidence intervals are reported for each park in each year.

Results

Mean percent cover (and 95% confidence intervals) are reported for each site at KATM, KEFJ and PWS in Figures 1 through 9. Relative abundance varied by region and tidal elevation, but

Fucus distichus subsp. evanescens, barnacles, and *Alaria marginata* were generally the most abundant. Notable differences between regions were observed at the lower (0.5 m MLLW – mean low low water) tidal elevation, with a greater percent cover of *Fucus* at KEFJ. The only notable trend over time was an increase in cover by *Fucus* at the 1.5 m tidal elevations at KEFJ between 2008 and 2011. No differences between regions were noted for the mean size of the limpet *Lottia persona* (Figure 10).

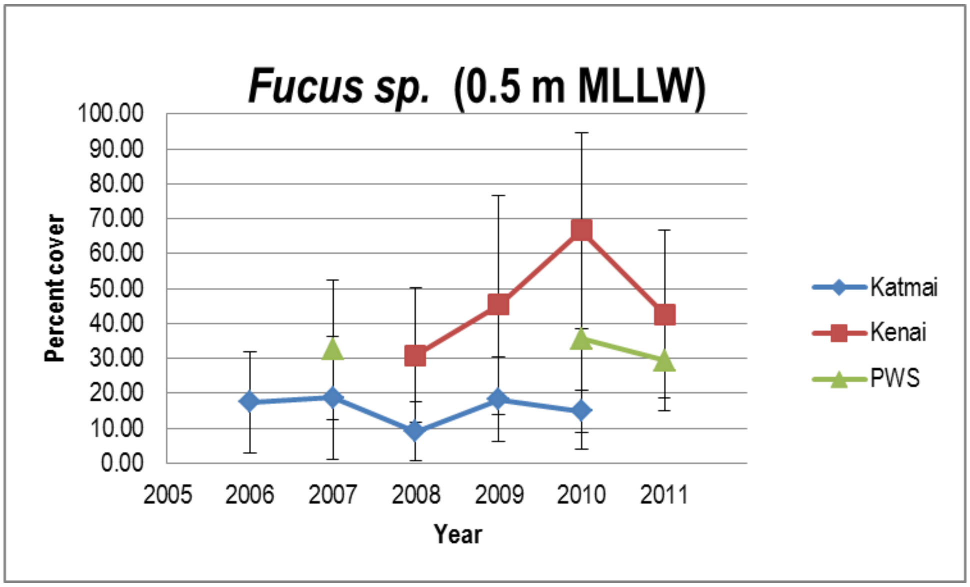

Figure 1. Percent cover of *Fucus* at the 0.5 m MLLW in KATM, KEFJ and PWS, 2006-2011. Error bars indicate 95% CI.

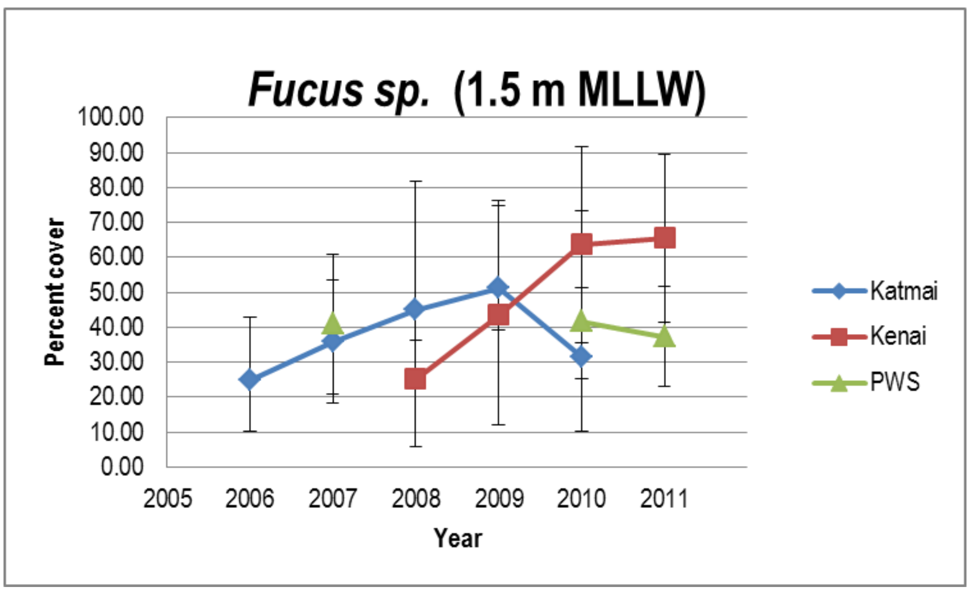

Figure 2. Percent cover of *Fucus* at the 1.5 m MLLW in KATM, KEFJ and PWS, 2006-2011. Error bars indicate 95% CI.

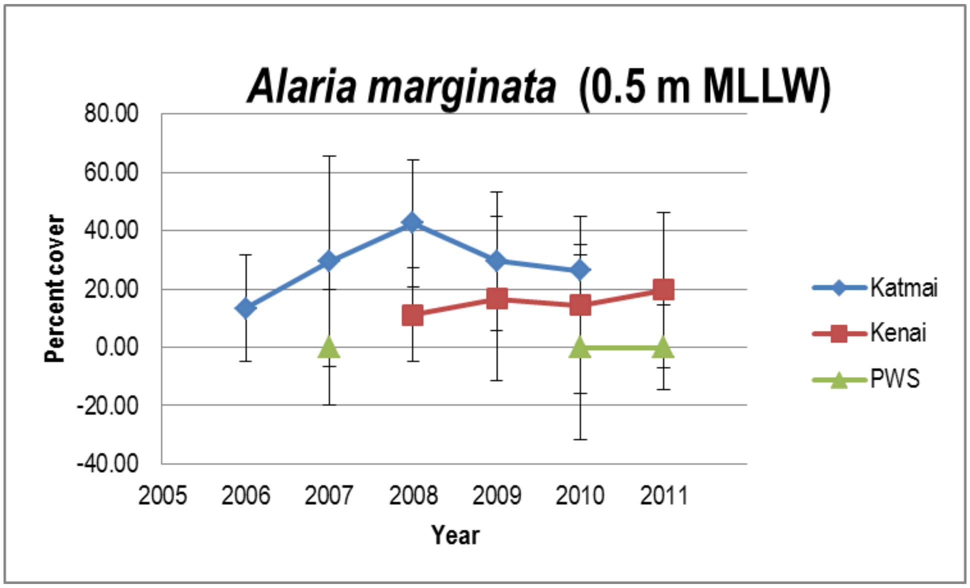

Figure 3. Percent cover of *Alaria* at the 0.5 m MLLW in KATM, KEFJ and PWS, 2006-2011. Error bars indicate 95% CI.

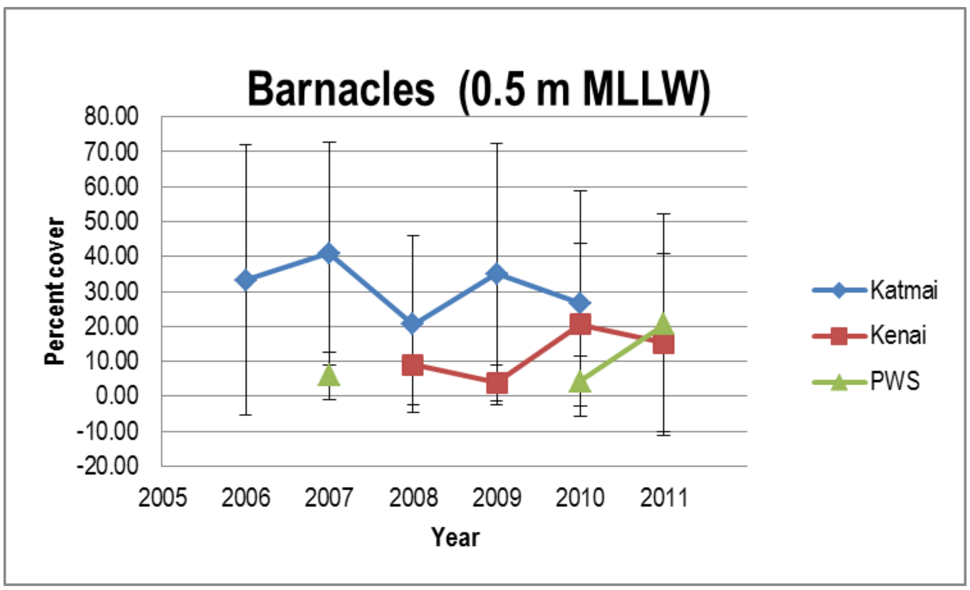

Figure 4. Percent cover of barnacles at the 0.5 m MLLW in KATM, KEFJ and PWS, 2006-2011. Error bars indicate 95% CI.

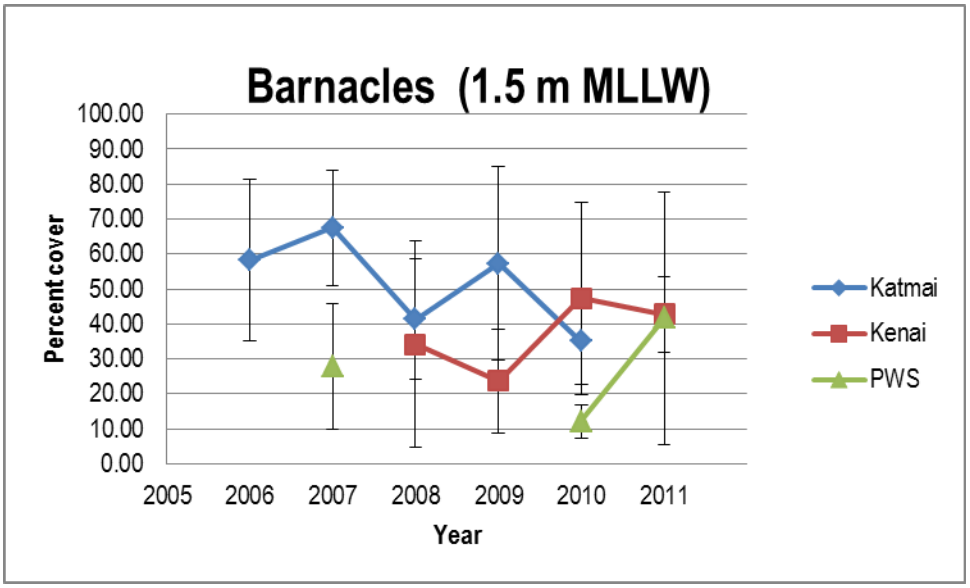

Figure 5. Percent cover of barnacles at the 1.5 m MLLW in KATM, KEFJ and PWS, 2006-2011. Error bars indicate 95% CI.

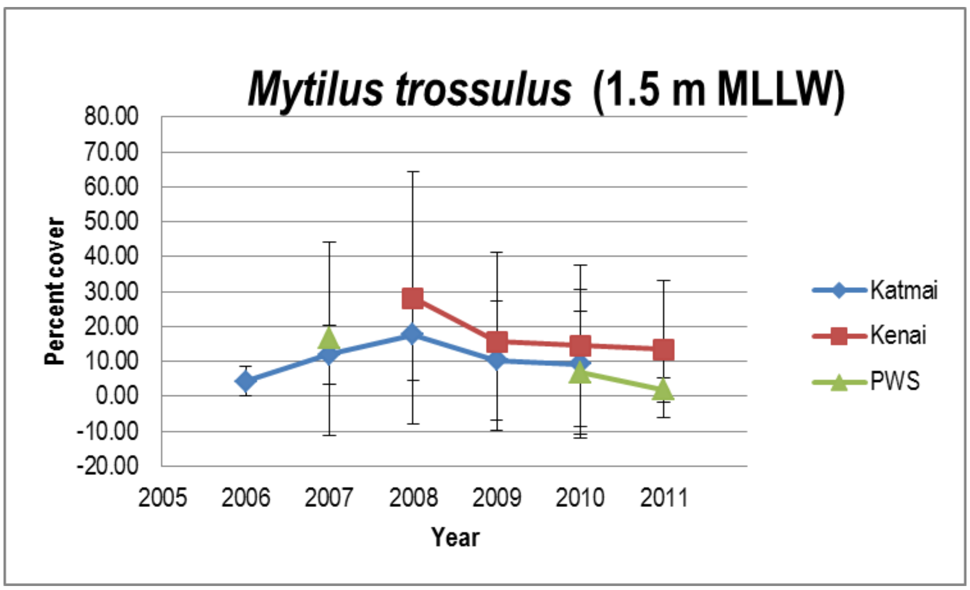

Figure 6. Percent cover of *Mytilus* at the 1.5 m MLLW in KATM, KEFJ and PWS, 2006-2011. Error bars indicate 95% CI.

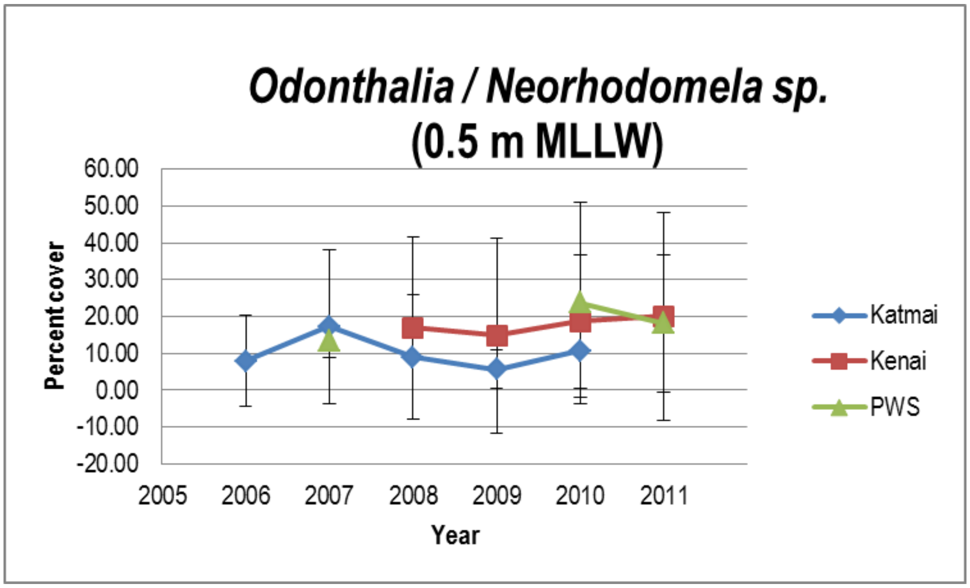

Figure 7. Percent cover of *Odonthalia / Neorhodomela* at the 0.5 m MLLW in KATM, KEFJ and PWS, 2006-2011. Error bars indicate 95% CI.

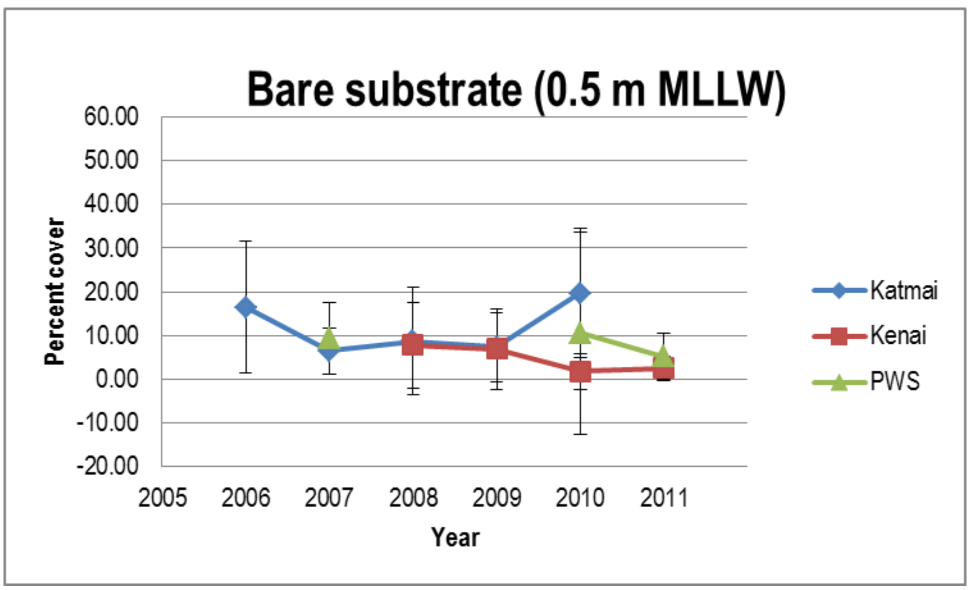

Figure 8. Percent cover of bare substrate at the 0.5 m MLLW in KATM, KEFJ and PWS, 2006-2011. Error bars indicate 95% CI.

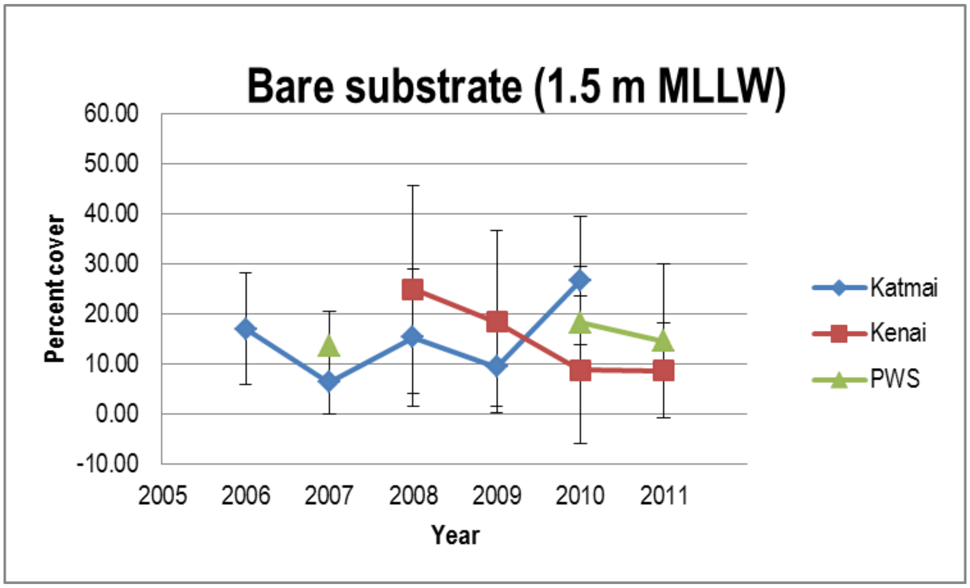

Figure 9. Percent cover of bare substrate at the 1.5 m MLLW in KATM, KEFJ and PWS, 2006-2011. Error bars indicate 95% CI.

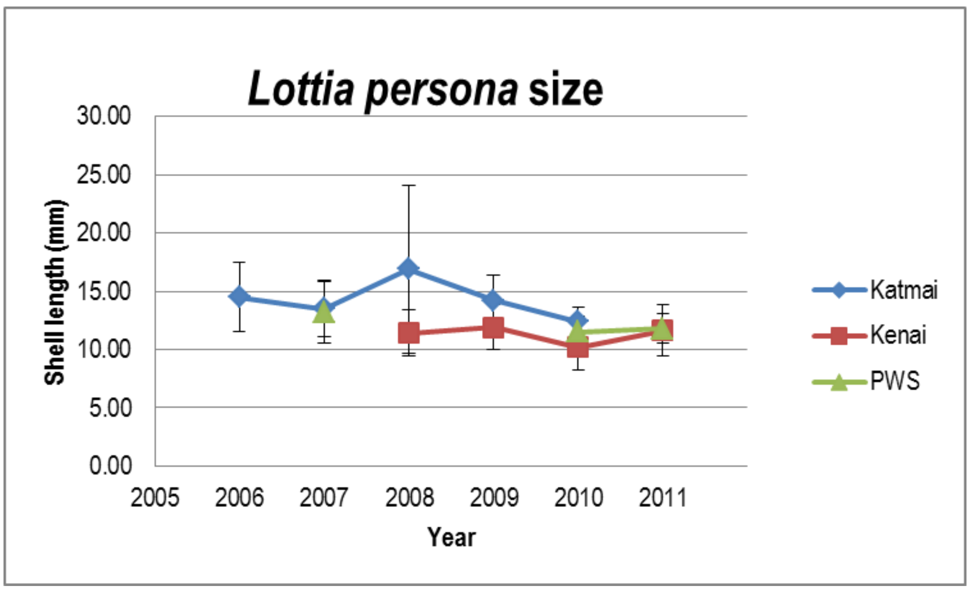

Figure 10. Mean size of *Lottia persona* in KATM, KEFJ and PWS, 2006-2011. Error bars indicate 95% CI.

Discussion

The sampling described provided reasonable estimates of the abundance of intertidal invertebrates and algae (including intertidal kelps) at sites within each region. We anticipate that the methods employed will detect ecologically meaningful levels of change in the future. Existing data will allow the program to begin trend analysis for several metrics and will be used in simulations to estimate number of samples and sample frequency required to detect a specified trend or change with some level of confidence for selected metrics, specifically the rocky intertidal algae and invertebrate vital sign. The rocky intertidal invertebrate and algae vital sign has eight (8) metrics that have several years of data to conduct simulations to determine the power to detect change. The levels of change or trend have already been specified by the investigators (Dean and Bodkin 2011a). The Vital Signs Monitoring Plan for SWAN explicitly states the use of hierarchical models to estimate trends. The work proposed here is to assist the National Park Service in the modification of the protocol for its monitoring program.

Recommendations

Based on these results, we recommend continued estimation of percent cover by sessile invertebrates and algae using random point counts and continued estimation of sizes of limpets.

Mussel Bed Sampling

Introduction

Pacific blue mussels (*Mytilus trossulus*) are a dominant invertebrate in the intertidal zone and are critically important prey for a variety of organisms including sea otters, black oystercatchers, harlequin ducks, Barrow's goldeneyes, and several species of sea stars (O'Clair and Rice 1985, O'Clair and O'Clair 1988, VanBlaricom 1988, Andres and Flaxa 1995, Esler et al. 2002, Bodkin et al. 2002). Mussels are widely distributed in many intertidal habitats, but also form relatively monotypic stands of larger individuals that are termed mussel beds. The goal of mussel bed sampling is to assess changes in the size of beds and in the size of mussels within those beds over time. These data are primarily to be used as an indicator of mussel abundance as prey for various predators (sea stars, sea ducks and sea otters). Specifically, the objectives are to estimate: 1) the density of mussels within these beds, 2) the density of large mussels (greater than or equal to 20 mm in length) within these beds, and 3) the size distribution of the large mussels within the beds (those generally consumed by black oystercatchers, sea ducks and sea otters). We define mussel beds as sites with relatively high densities of mussels. Specifically, mussel beds are defined as areas with greater than approximately 10% cover by mussels within contiguous 0.25 m^2 quadrats over areas of 100 m^2 or greater. Metrics used to evaluate change over time will include the area of individual mussel beds (in m^2), average density of large mussels, and the mean size of large mussels. In this report, we include results of sampling mussels at sites in KATM and KEFJ.

Methods

Sampling sites are defined as 50 m of coastline with contiguous mussel beds. These sites were selected following intensive searches in 2008 for the presence of mussel beds adjacent to the randomly selected rocky intertidal sites (see intertidal invertebrates and algae section). The closest mussel bed to the randomly selected rocky intertidal site was selected for sampling.

A transect 50 m in length was established through the mid-point of the bed, relative to tidal elevation, and at the left end of the bed, as observed from the water. A permanent bolt was placed at this location and at approximately 5 m intervals along the 50 m length of the horizontal transect to establish the site for future sampling. Ten vertical transects were then established at systematic intervals based on a random start point (a different random start point is used each year) along the horizontal transect length, and the distance from the upper most margin of the bed to the lower margin (or the 0 m tidal elevation) was measured for each vertical transect.

Estimates of mussel density are made within quadrats that are randomly located along each vertical transect. Quadrat dimensions are dependent on the density of mussels $\geq$ 20 mm within 1 m of the predetermined random point along the vertical transect, and determined at the time of sampling. The quadrat size can range from .0025 m^2 to 1.00 m^2 (5 cm to 100 cm on a side) with the size dependent on obtaining a collection of at least 20 mussels $\geq$ 20 mm in length. This results in at least 200 mussels to estimate size distributions at a site. All mussels $\geq$ 20 mm are collected from within the quadrat and later counted and measured, and densities of large mussels are calculated. Densities of all mussels (of a size that is visually detectable, approximately 5 mm and greater) are estimated from a 2.54 cm radius (20.27 cm^2) core located at the same random number that defined the vertical quadrat, but on the opposite side of the tape from the origin of the large mussel quadrat.

Results

In 2011 we estimated the abundance and size of mussels at five mussel bed sites at five sites in KEFJ for the fourth year in a row. KATM was not sampled in 2011. Results for each park are represented here. In general, mussel density is greater in KEFJ than in KATM for all mussels including the large mussels (Figures 11 and 12). Mussel sizes are greater in KATM than KEFJ, but not significantly (Figure 13). The proportion of large mussels appears to have decreased in KEFJ in 2011 (Figure 14). These results, however, are not significant.

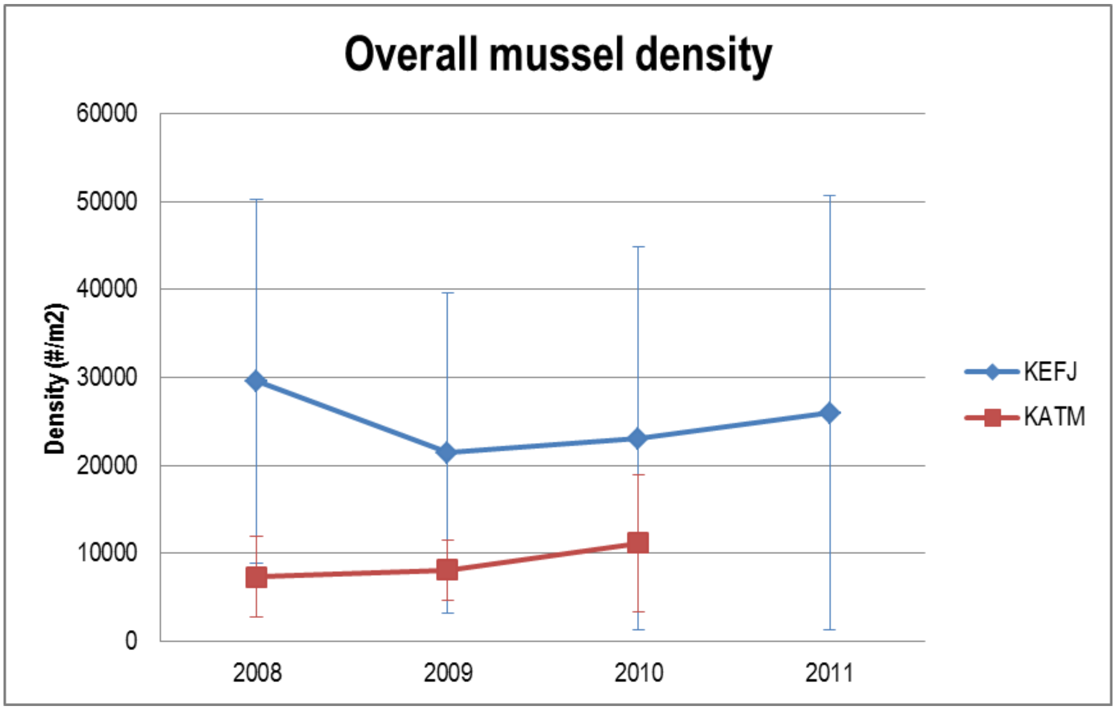

Figure 11. Overall mussel density (#/m^2) in KATM and KEFJ, 2008-2011. Error bars indicate 90% CI.

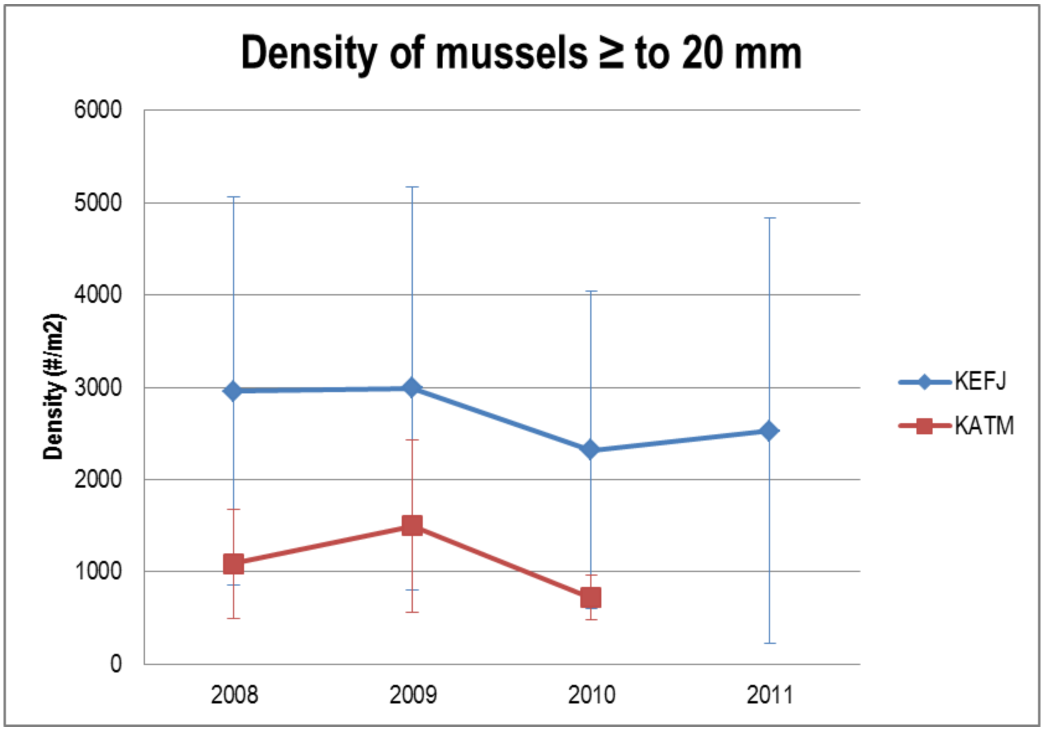

Figure 12. Density (#/m^2) of mussels ≥ 20 mm in KATM and KEFJ, 2008-2011. Error bars indicate 95% CI.

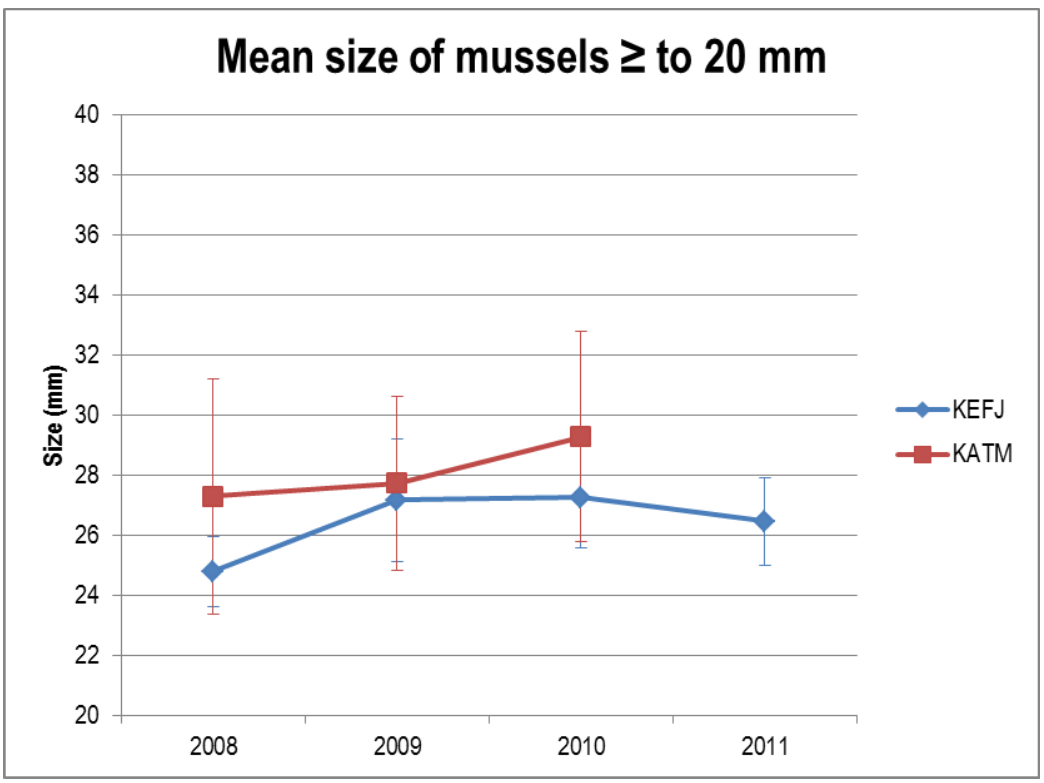

Figure 13. Mean size of mussels ≥ 20 mm in KATM and KEFJ, 2008-2011. Error bars indicate 95% CI.

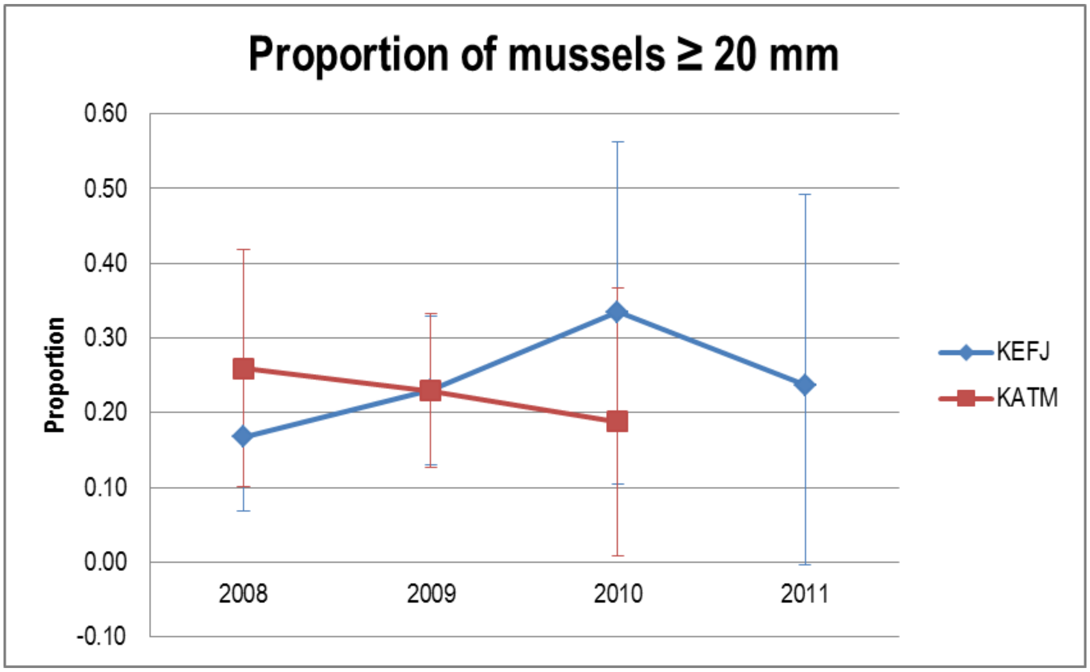

Figure 14. Proportion of mussels ≥ 20 mm in KATM and KEFJ, 2008-2011. Error bars indicate 90% CI.

Discussion

Using the methods briefly described above, we were able to estimate densities of mussels, the size distribution and density of large mussels (≥ 20 mm), and the proportion of large mussels. Mussel densities varied greatly between parks, both in terms of all mussels and large mussels. Mean sizes of large mussels were relatively uniform among all sites, indicated by the smaller error bars. The high uniformity in mean sizes and low variance among sites, suggest perhaps common mechanisms structuring the sizes of mussels in the parks. While evaluating variance estimates of mussel densities and sizes for sensitivity to detect change will require additional years of data, the relatively low variation in mean sizes of large mussels across sites continues to suggest that mussel size may provide a statistically powerful metric to detect change over time.

Recommendations

Our fourth year of descriptive analysis indicates that sizes of mussels may provide a metric sensitive to change both among and within sites. We recommend the continuation of annual mussel bed sampling. Similar to the algae analysis discussed in the previous section, existing mussel bed data will allow the program to begin trend analysis for several metrics and will be used in simulations to estimate number of samples and sample frequency required to detect a specified trend or change with some level of confidence for selected metrics, specifically the rocky intertidal algae and invertebrate vital sign. The levels of change or trend have already been specified by the investigators (Dean and Bodkin 2011a). The Vital Signs Monitoring Plan for SWAN explicitly states the use of hierarchical models to estimate trends. The work proposed here is to assist the National Park Service in the modification of the protocol for its monitoring program.

Eelgrass Bed Sampling

Introduction

Eelgrass (*Zostera marina*) is the dominant seagrass in protected waters of the Gulf of Alaska and is broadly distributed in sheltered embayments, especially in habitats dominated by soft sediments where they often form "beds" or relatively monotypic stands that can cover much of the shallow (0 to 5 m depth) subtidal zone (McRoy 1968, 1970). Eelgrass is an important "living habitat" that serves as a nutrient filter, provides shelter for fish and a variety of invertebrates, and provides physical substrate for invertebrates and algae (Thayer and Phillips 1977, Jewett et al. 1999, Dean et al. 2000, Bostrom et al. 2006). Eelgrass is a major primary producer in the marine nearshore (McConnaughey and McRoy1979) and because it is located in shallow water, is susceptible to oil spills and other human disturbances (Short and Wiley-Eschevaria 1996, Dean et al. 1998, Duarte 2002, Larkum et al. 2006, Short et al. 2006). Eelgrass is especially susceptible to dredging, anchor scars, and events that reduce light penetration into the water column such as runoff (increased turbidity) or nutrient addition (Walker et al. 1989, Oleson 1996, Hauxwell et al. 2003, Neckles et al. 2005, Terrados et al. 2006).

The purpose of this sampling is to assess changes in the extent of eelgrass over time. In this report, we examine results from sampling eelgrass cover in KATM and KEFJ. The sampling is designed to examine smaller spatial scales (within beds of approximately 1 km^2) over temporal scales of several years.

Methods

We sampled the percent cover of eelgrass at four sites in KATM in 2010 and at five sites in KEFJ in 2011 (four sites in 2010). Future sampling will consist of annual visits to 5 sites in each park. The same designated area will be sampled at each site in each year. All sampling will be conducted in early summer when eelgrass beds generally have reached their seasonal maximum in extent and density of plants.

All beds sampled were in sheltered bays and were at beds in closest proximity to the randomly selected rocky intertidal sites (see intertidal invertebrates and algae section). At each site, we sampled eelgrass within a prescribed area along a shoreline of approximately 200 m in length. The width of each bed examined depended on the depth contour at each site, but was generally on the order of 50 to 100 m. The areas sampled were bounded by an approximately 200 m segment of shoreline over which eelgrass was observed and extended offshore to a distance approximately 15 m beyond the last observed eelgrass. The percent cover of eelgrass within this area was estimated by determining the presence or absence of eelgrass at approximately evenly spaced intervals along a series of transects running perpendicular to shore that were spaced approximately 20 m apart. Presence or absence at each observation point was determined using an underwater video camera lowered from a small inflatable boat and a single-beam sonar.

These surveys will allow us to detect changes in average extent of eelgrass over time. While we do not know the types of changes that might occur, these might include local reduction in cover due to increased boating activity and associated anchor scars, a lowering of the upper depth limitation due to a decline in water clarity, or larger scale die offs due to diseases or contaminants.

Results

The percent of observations with eelgrass present ranged from 25% to 73%. The highest percent covers observed in KATM were at Amalik Bay in 2010. The highest percent covers observed in KEFJ were Harris Bay in 2010 and Nuka Pass in 2011.

Table 1. Percent of observations with eelgrass at sites in KATM in 2010. KATM was not sampled in 2011. Means and 90% confidence intervals (mean plus or minus CI) are given. Dots indicate 'no data'.

			Proportion of observations with eelgrass present	
Region	**Site Name**	**Site ID**	**2010**	**2011**
KATM	Kukak	EI1	0.56	.
KATM	Kaflia	EI2	0.50	.
KATM	Amalik	EI4	0.60	.
KATM	Takli	EI5	0.38	.
KATM	Mean	All Sites	0.51	.
KATM	CI	All Sites	0.08	.

Table 2. Percent of observations with eelgrass at sites in KEFJ in 2010 and 2011. Means and 90% confidence intervals (mean plus or minus CI) are given. Dots indicate 'no data'.

			Proportion of observations with eelgrass present	
Region	**Site Name**	**Site ID**	**2010**	**2011**
KEFJ	Aialik Bay	EI1	0.25	0.28
KEFJ	McCarty	EI2	0.32	0.35
KEFJ	Nuka Bay	EI3	0.67	0.61
KEFJ	Nuka Pass	EI4	.	0.68
KEFJ	Harris Bay	EI5	0.73	0.35
KEFJ	Mean	All Sites	0.49	0.45
KEFJ	CI	All Sites	0.2	0.13

Discussion

Using the methods briefly described above, we were able to estimate percent cover by eelgrass in prescribed areas. Determination of our ability to detect change in eelgrass cover over time will require additional years of sampling.

Recommendations

Based on replicate sampling completed in 2008 (Coletti et al. 2009), our analysis indicated that the method produces relatively precise estimates of the relative abundance of eelgrass. We recommend the continuation of annual eelgrass bed sampling.

Marine Bird Surveys

Introduction

Marine birds and mammals are important constituents of marine ecosystems and are sensitive to variation in marine conditions. Our focus on nearshore marine bird monitoring will be on species that are relatively abundant and trophically linked to the nearshore food web where the kelps and seagrasses contribute substantially to primary productivity and benthic invertebrates, such as clams, mussels and snails, transmit that energy to higher level trophic level fishes, birds and mammals. Species of focus in the nearshore food web include black oystercatchers, cormorants, glaucous-winged gulls, black-legged kittiwakes, goldeneyes (winter density and distribution), harlequin ducks, pigeon guillemots, mergansers and scoters. Because other birds and mammals will be encountered in the course of monitoring nearshore species, observations of all marine birds and mammals are recorded.

The sea ducks and black oystercatcher were selected for focus because of their reliance on habitats and prey associated with nearshore marine communities. These species play an important role as top level consumers of nearshore invertebrates, including mussels, clams, snails, and limpets, that are being monitored under the intertidal invertebrates and algae component (Draulans 1982, Marsh 1986a and b, Meire 1993, Lindberg et al. 1998, Hamilton and Nudds 2003, Lewis et al. 2007). Therefore, understanding changes in the abundance of these bird species over time is an important metric for nearshore monitoring. Abundance estimates will be enhanced by the monitoring of nearshore invertebrates, which focuses on their prey populations. Moreover, monitoring trends in abundance of the various guilds of other marine birds (e.g. pigeon guillemots, black-legged kittiwakes, and cormorants) that utilize other food sources may improve the ability to discriminate among potential causes of change in seabird populations and the nearshore ecosystem. For example, concurrent changes in sea ducks, which forage on nearshore invertebrates, and the pigeon guillemots that forage on small fish, may suggest a common cause of change, one that may be independent of food. Such an approach may provide insights related to competing hypotheses relative to cause of change within or among populations (Petersen et al. 2003). In addition many of these species, including the harlequin duck, Barrow's goldeneye, and black oystercatcher, were impacted by the Exxon Valdez oil spill, and exhibited protracted recovery periods as a consequence of lingering oil in nearshore habitats in Prince William Sound (Andres 1999, Trust et al. 2000, Esler et al. 2000a and b, Esler et al. 2002). Long-term monitoring of these species at different locations will likely provide increased confidence in assessment of the status of these populations relative to restoration and recovery from the 1989 spill. Additionally, existing data collected using comparable methods are available from other nearshore habitats in the Gulf of Alaska for periods up to 20 years (Irons et al.1988, Irons et al. 2000).

Methods

Standardized surveys of marine birds were conducted in KATM (2006-2010) and KEFJ (2007-2011) between late June and early July. Surveys are conducted from small vessels (5-8 m length) traveling at speeds of 8-12 knots along selected sections of coastline that represent independent transects. The transect width is 200 m and the boat represents the midpoint. Transects are surveyed by a team of three. The boat operator generally surveys the 100 m offshore area of the transect, while a second observer surveys the 100 m nearshore area. The third team member enters the observations into a laptop running dLOG, specifically designed for this type of surveying, and assists with observations. All marine birds and mammals within the 200 m transect width are identified and counted. All transects considered in this analysis are run 100 m offshore and parallel to the shoreline. Detailed descriptions of methods and procedures can be found in the Marine Bird and Mammal Survey SOP (Bodkin 2011a).

The survey design consists of a series of transects along shorelines such that a minimum of 20% of the shoreline is surveyed. Transects are systematically selected beginning at a random starting point from the pool of contiguous 2.5-5 km transects that are adjacent to the mainland or islands, plus the lengths of transects that were associated with islands or groups of islands with less than 5 km of shoreline.

Each species is identified as important to nearshore food webs and as an important indicator of change (Dean and Bodkin 2011a). Several species were grouped into higher order taxa (e.g., cormorants, mergansers and scoters) because identification to species within these groups was not always possible. Cormorant species included pelagic, red-faced, and double crested cormorants. Merganser species include common merganser and red-breasted mergansers. Scoters included surf, black, and white-winged scoters.

Results

Summer surveys were conducted only in KEFJ in 2011. Only focal species densities and standard errors observed on nearshore transects are reported here (Figures 15-22).

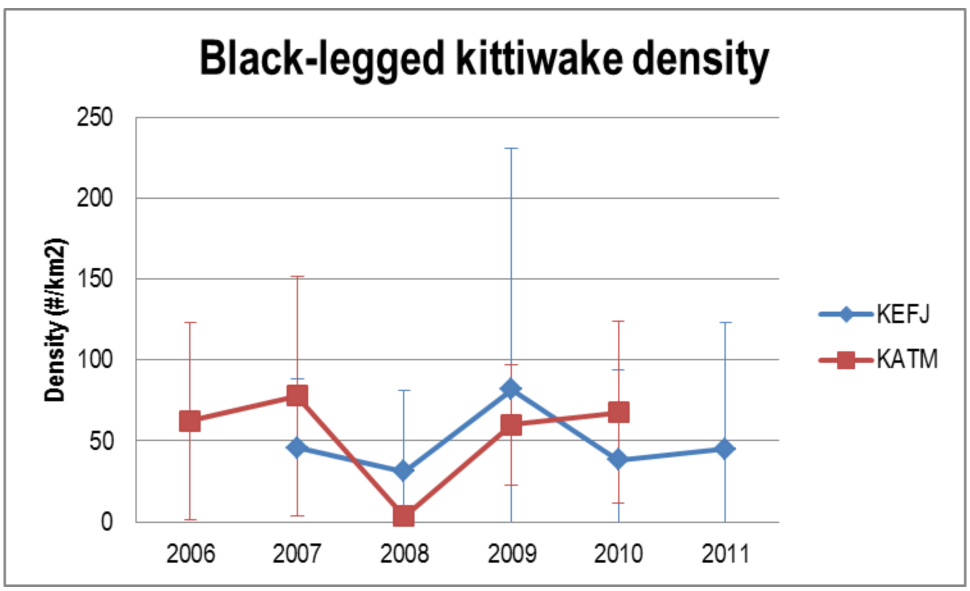

Figure 15. Density of black-legged kittiwake in KATM and KEFJ, 2006-2011. Error bars indicate 95% CI.

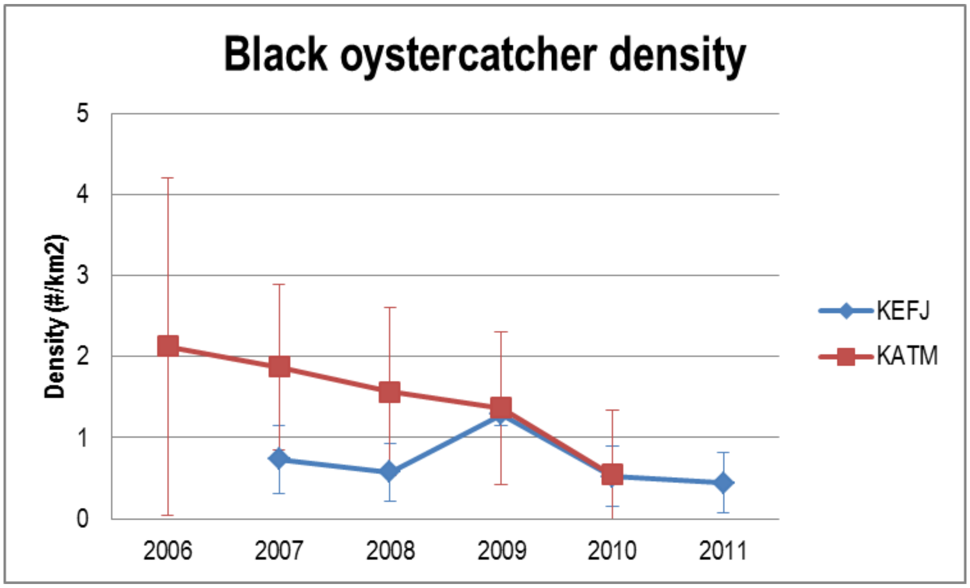

Figure 16. Density of black oystercatcher in KATM and KEFJ, 2006-2011. Error bars indicate 95% CI.

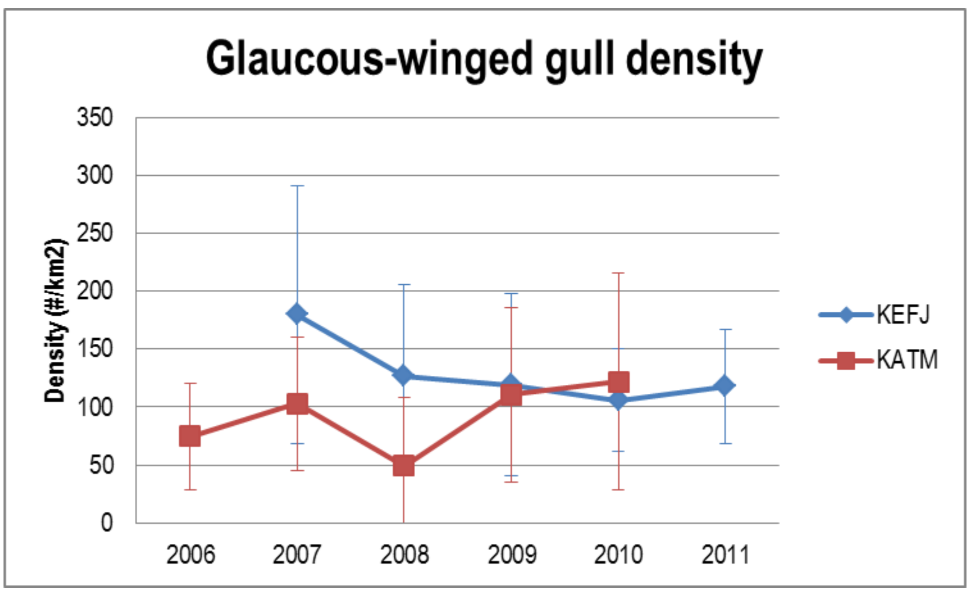

Figure 17. Density of glaucous-winged gull in KATM and KEFJ, 2006-2011. Error bars indicate 95% CI.

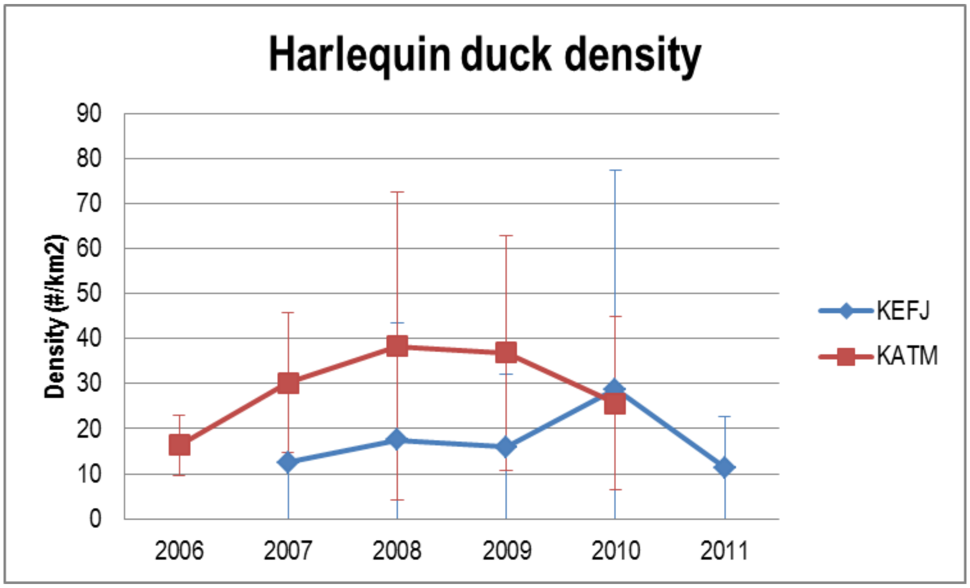

Figure 18. Density of Harlequin duck in KATM and KEFJ, 2006-2011. Error bars indicate 95% CI.

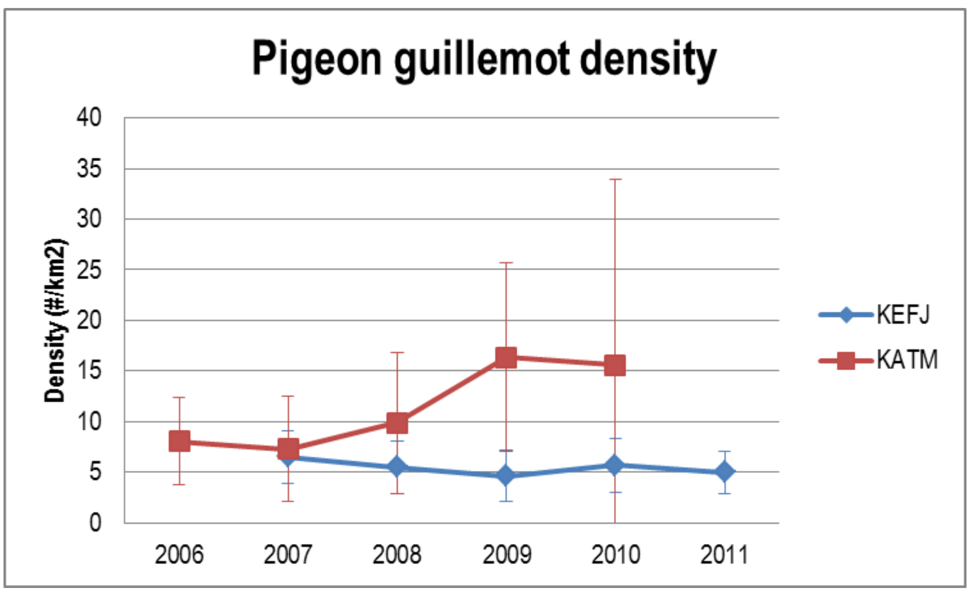

Figure 19. Density of pigeon guillemot in KATM and KEFJ, 2006-2011. Error bars indicate 95% CI.

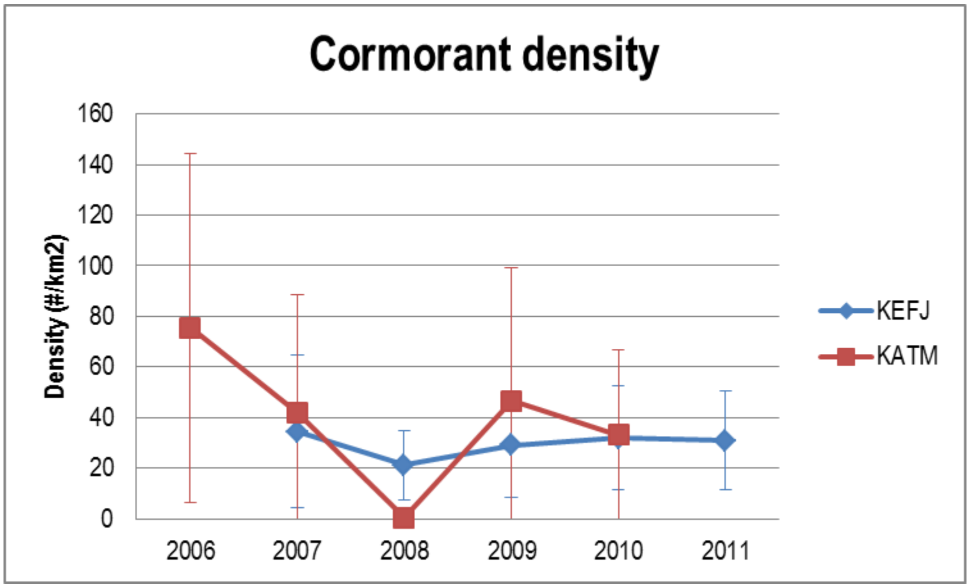

Figure 20. Density of cormorants in KATM and KEFJ, 2006-2011. Error bars indicate 95% CI.

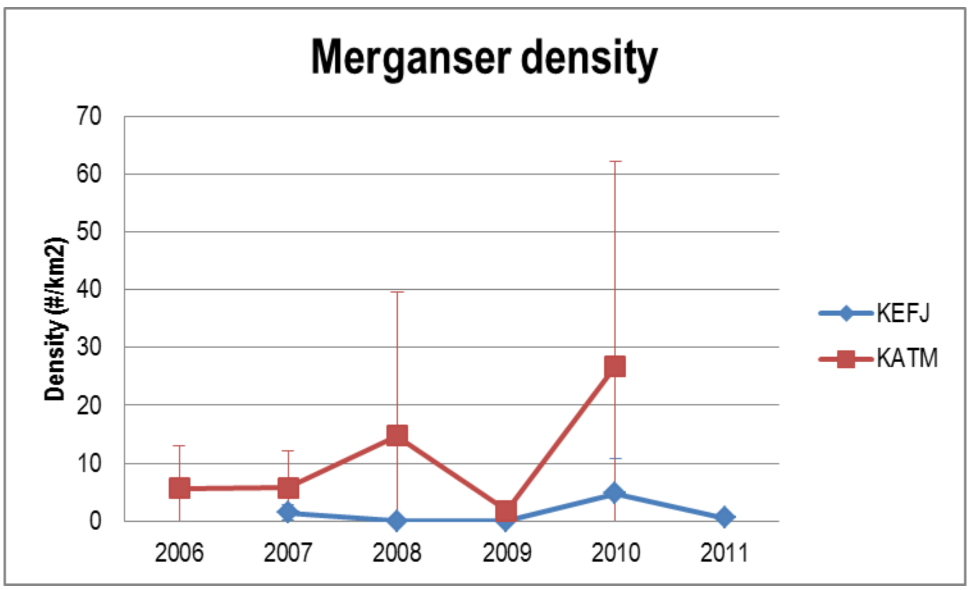

Figure 21. Density of mergansers in KATM and KEFJ, 2006-2011. Error bars indicate 95% CI.

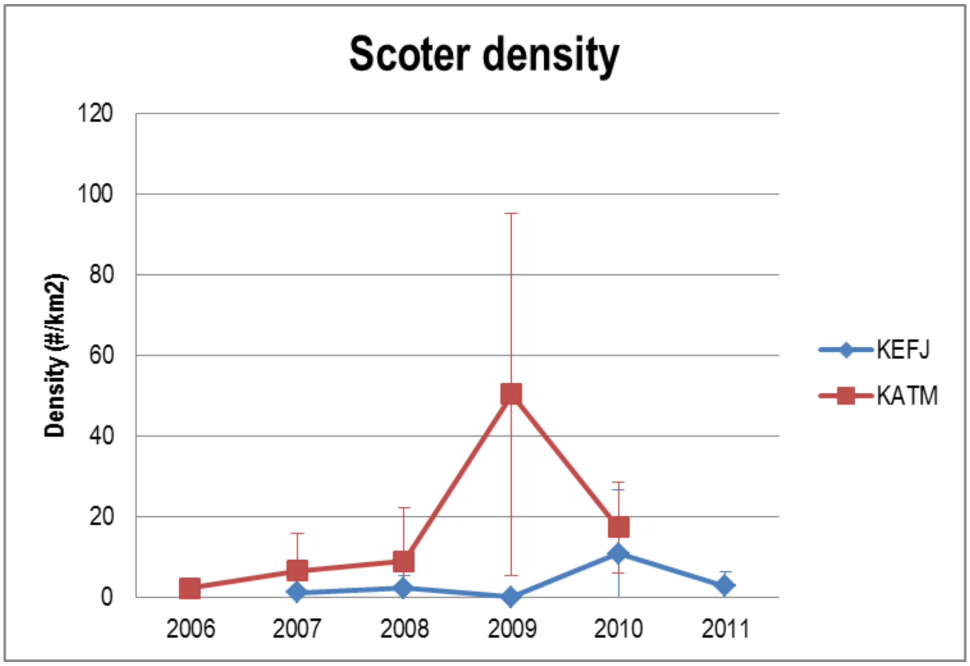

Figure 22. Density of scoters in KATM and KEFJ, 2006-2011. Error bars indicate 95% CI.

Discussion

KATM and KEFJ continue to be sampled annually during the summer. These shoreline skiff surveys provide baseline information on species composition, distribution and density for summer populations of marine bird and mammal fauna that occur in the nearshore waters of KATM and KEFJ. Because components of the marine bird and mammal fauna may change seasonally, inference of species composition, distribution, and densities to other seasons cannot be made. In particular, it is likely that some sea duck species that were rare or absent in the summer may be more common as over wintering residents (e.g. goldeneye, scoters, and long tailed ducks). Sustainability of long-term monitoring programs requires the optimization of sampling intensity and efforts to minimize costs while concurrently having sufficient power to detect a trend. While there has been critical thought in the past regarding these questions, current available analytical methods now allow for the use of existing data to estimate number of samples and sample frequency required to detect a specified trend as well as examine effects contributing to variation, such as imperfect detection. An optimization exercise using existing data will occur in 2011-2014.

Recommendations

We recommend that survey effort continue until further analysis can be completed. These datasets will be examined to determine levels of change that we can reasonably expect to detect based on this sampling method. We will also explore the possibility of re-allocating sampling efforts to specific habitat types or incorporate replicate sampling to enhance our ability to detect trends for species of interest.

Black Oystercatcher Sampling

Introduction

The black oystercatcher is a common and conspicuous member of the rocky and gravel intertidal marine communities of eastern Pacific shorelines and is completely dependent on nearshore marine habitats for all critical life history components including foraging, breeding, chick-rearing, and resting (Andres and Falxa 1995). During the late spring and summer breeding season pairs establish and defend both nest and forage areas, and these territories and nest sites can persist over many years (Groves 1984, Hazlitt and Butler 2001) with individual life expectancy exceeding 15 years (Andres and Falxa 1995). The diet consists primarily of mussels (*Mytilus* sp.) and a variety of limpets (*Lottia, Acmea*, and *Colisella* sp.) (Andres and Falxa 1995), which are ecologically and culturally important constituents of the intertidal community. The species is considered a Management Indicator Species by the Chugach National Forest and a species of concern nationally (Brown et al. 2001) and regionally (Alaska Shorebird Working Group 2000), and is widely recognized as a species representative of nearshore habitats. Because of their complete reliance on intertidal habitats, their reproductive biology, and foraging ecology, black oystercatchers are particularly amenable to long-term monitoring (Lentfer and Maier 1995, Andres 1998).

As a “keystone” species (Power et al. 1996), the black oystercatcher has a large influence on the structure of intertidal communities that is disproportionate to its abundance. The black oystercatcher receives its recognition as a keystone species through a three-trophic-level cascade initiated by the oystercatcher as a top level consumer in the nearshore (Marsh 1986a and b, Hahn and Denny 1989, Falxa 1992) whose diet consists largely of gastropod (limpets) and bivalve (mussels) mollusks that are ecologically important in the intertidal community. As a consequence of oystercatcher foraging, large numbers of herbivorous limpets can be removed (Frank 1982, Lindberg et al. 1987), resulting in shifts in limpet species composition and reduced size distribution (Marsh 1986a, Lindberg et al. 1987). As a consequence of reduced limpet densities and the diminished grazing intensity that results, algal populations respond through increased production and survival, resulting in enhanced algal populations (Marsh 1986a, Meese 1990, Wootton 1992, Lindberg et al. 1998). Additionally, like other invertebrate, avian and mammalian predators in the nearshore, a large fraction of the oystercatcher’s diet consists of mussels, an important filter feeding bivalve (Knox 2000, Menge and Branch 2001). Because the oystercatcher brings limpets, mussels and other prey back to its nest to provision chicks (Webster 1941, Frank 1982, Hartwick 1976, Lindberg et al. 1987), collections of those shell remains at nests provides an opportunity to obtain an independent sample of the species composition and size distribution of common and important nearshore invertebrate prey species that are directly estimated under intertidal algal and invertebrate vital signs (Intertidal Invertebrates and Algae section of this report). The collection of black oystercatcher diet and prey data offers a unique perspective into processes structuring nearshore communities (Marsh 1986a and b, Lindberg et al. 1987), including the potential consequences of anticipated increases in human presence and disturbance (Lindberg et al. 1998). Further, contrasting relative abundances and size-class composition of invertebrates collected under two independent protocols should increase our understanding of the processes responsible for change in nearshore ecosystems.

At a global scale, intertidal communities have been impacted by human activities (Liddle 1975, Kingsford et al. 1991, Povery and Keough 1991, Keough et al. 1993, Menge and Branch 2001) and one of the primary capabilities and intents of the nearshore monitoring program is to provide early detection of change in nearshore communities and to separate human from natural causes of change. Because of the critical nature of intertidal habitats for both breeding and foraging, black oystercatchers are particularly sensitive indicators to disturbances in the nearshore (Lindberg et al. 1998). Specifically, black oystercatchers nest exclusively in a narrow band just above the intertidal but below terrestrial vegetation, where eggs are laid in exposed nests consisting of depressions in pebbles, sand, gravel, and shell materials. During the 26-32 d incubation phase of reproduction, eggs are susceptible to predation by other birds (primarily C*orvids*; Lentfer and Meier 1995) and mammals (Vermeer et al. 1992), as well as human disturbance and trampling. Similar disturbance effects occur during the chick rearing stage, which lasts approximately 38 d (Andres and Falxa 1995). Thus, for several months during May-August, typically when humans are most present in nearshore habitats in Alaska, black oystercatchers are actively incubating or caring for young in a habitat with little protection from human induced disturbances. Chronic disturbance from human activities poses a significant threat to breeding black oystercatchers, either preventing nesting altogether, causing nest abandonment after eggs have been laid (Andres 1998), or through direct mortality of eggs or chicks. Monitoring of black oystercatcher density, breeding territory density and occupancy, and prey will provide a potentially powerful tool in identifying the magnitude and causes of inevitable change in Gulf of Alaska nearshore habitats and communities, particularly in response to the anticipated increased use and influence of those habitats by humans.

Methods

There are three components to the sampling related to black oystercatchers: estimation of breeding pair density and nest occupancy through oystercatcher-specific surveys; estimation of species composition and size distributions of prey returned to provision chicks; and density estimation of breeding and non-breeding black oystercatchers observed during the marine bird and mammal surveys. Results regarding the black oystercatcher density estimates are given in the marine bird survey section of this report. Detailed survey methods for estimation of nest occupancy and diet can be found in the black oystercatcher breeding territory occupancy and chick diet SOP (Bodkin 20011b). The detailed methods used to obtain marine bird densities can be found in the marine bird SOP (Bodkin 2011a) and in Bodkin et al. (2007b and 2008).

Black oystercatcher breeding territory density, nest occupancy, and prey data were collected along five 20 km transects, with each centered on the randomly (GRTS) rocky intertidal algal and invertebrate sites at KATM since 2006 and KEFJ since 2007. Nest sites were located by surveying the shoreline in a small boat. All accessible nest sites were visited to determine the number of chicks and/or eggs present and all prey items (e.g. mussel or limpet shells) present at a nest site were collected. All prey were measured. Here, we present size data for most abundant prey species, Pacific blue mussels (*Mytilus trossulus*) and the limpets (*Lottia pelta*, *Lottia persona* and *Lottia scutum*).

Results

Density and Productivity

All five black oystercatcher GRTS transects were analyzed at the park level for nest density (nest/km) and productivity (chicks + eggs/nest) by year in KEFJ in 2011. KATM was not sampled in 2011. The mean density of active black oystercatcher nest sites at KATM ranged from 0.05 to 0.11 per km of shoreline from 2006-2010 (Figure 23). The mean density of active black oystercatcher nest sites at KEFJ ranged from 0.05 to 0.10 per km of shoreline from 2007-2011 (Figure 23). The mean productivity (eggs + chicks / nest) ranged from 1.42 to 2.3 eggs + chicks / nest for KATM from 2006-2010 (Figure 24). The mean productivity (eggs + chicks / nest) ranged from 0.27 to 1.92 eggs + chicks / nest for KEFJ from 2007-2011 (Figure 24). KEFJ showed a slight increase in both the number of active nests and productivity of active nests in 2011.

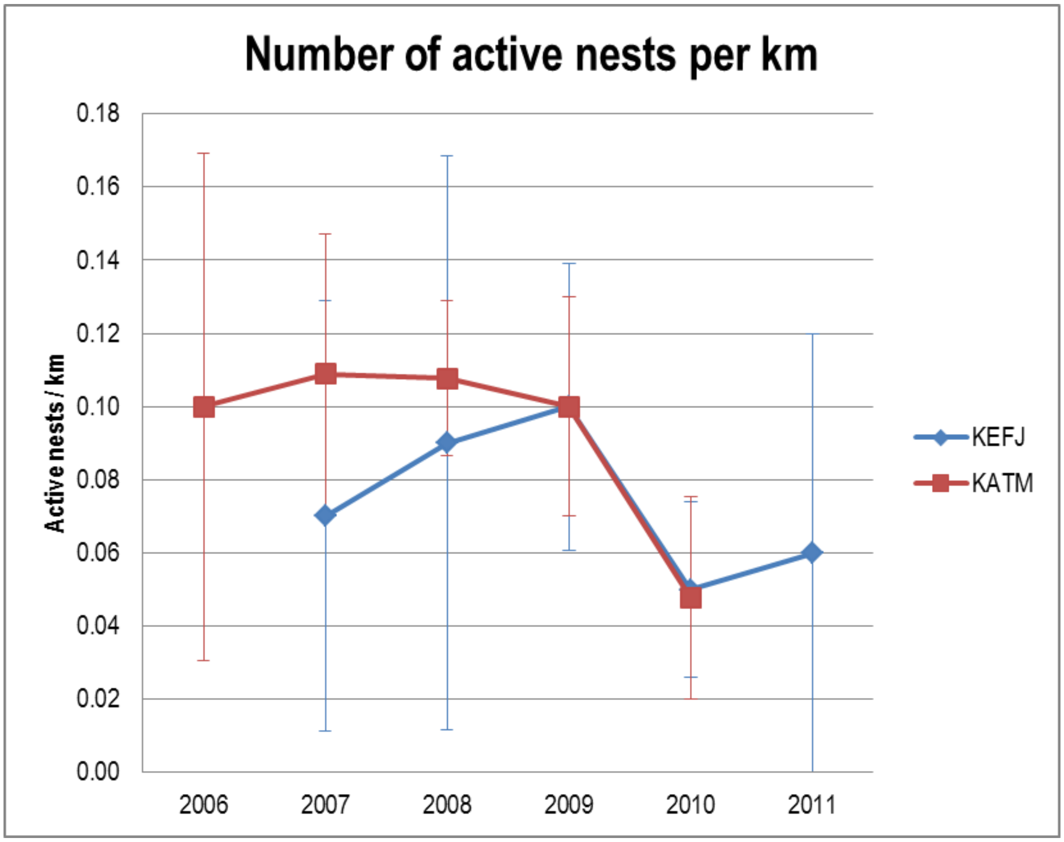

Figure 23. Number of active black oystercatcher nests / km in KATM and KEFJ, 2006-2011. Error bars indicate 95% CI.

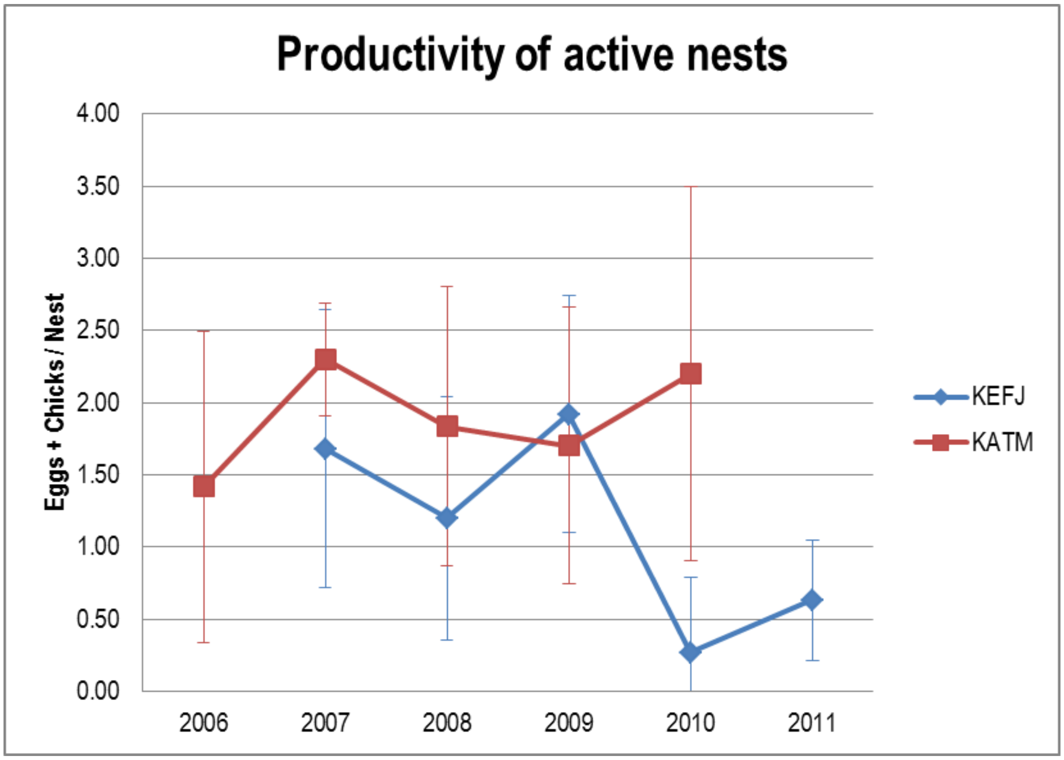

Figure 24. Productivity (eggs + chicks / nest) of active black oystercatcher nests / km in KATM and KEFJ, 2006-2011. Error bars indicate 95% CI.

Diet

Three species of limpets *(Lottia pelta, Lottia persona,* and to a lesser extent *Lottia scutum*) and the Pacific blue mussel (*Mytilus trossulus)* were the predominant prey items found at black oystercatcher nest sites in both KATM and KEFJ (Figures 25 and 26). Together these species represented 94% of prey items found at KATM (2006-2010) nest sites and 96% in KEFJ (2007-2009) for all sampling years. No prey items were observed or collected in KEFJ in 2010. Prey items were only available to be collected at two nests in KEFJ in 2011.

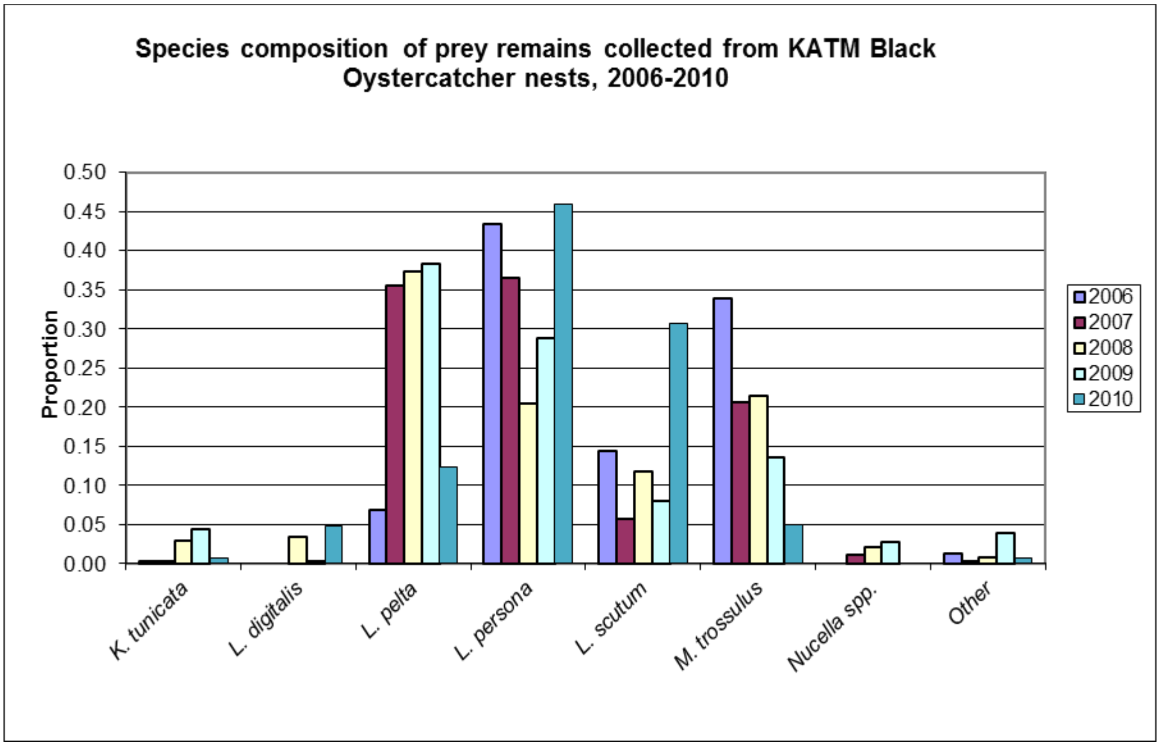

Figure 25. Species composition of prey items collected at active black oystercatcher in KATM, 2006-2010.

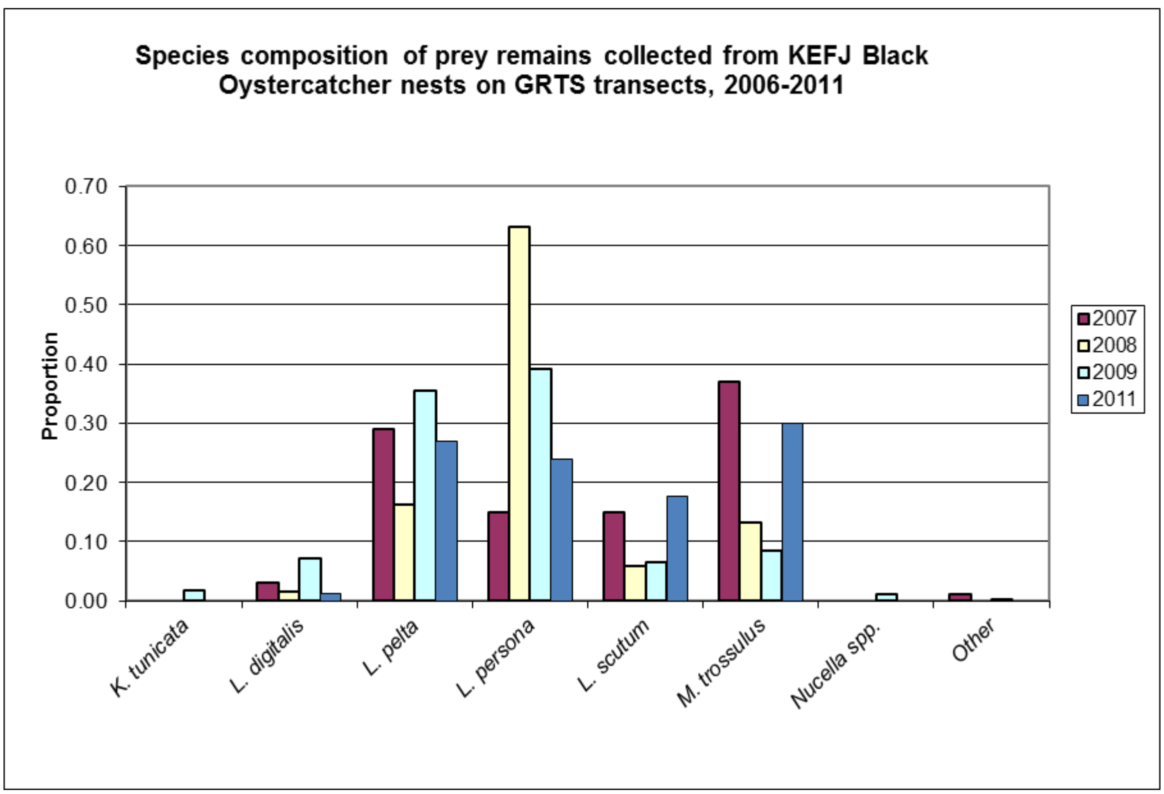

Figure 26. Species composition of prey items collected at active black oystercatcher in KEFJ, 2007-2011. No prey items were observed or collected in 2010.

Prey size is measured for all species. However, we report only on the mean size of two of the most predominate species, the limpet *Lottia persona* and the mussel, *Mytilus trossolus*. Both of the species are also monitored for density and size within the Sampling of Intertidal Invertebrates and Algae on Sheltered Rocky Shores SOP (Dean and Bodkin 2011b). Mean *L. persona* size ranged from 18.84 to 23.02 mm in KATM from 2006-2010 and ranged from 18.45 to 22.96 mm in KEFJ from 2007-2011 (no prey items observed in 2010) (Figure 27). Mean *M. trossulus* size ranged from 27.44 to 45.05 mm in KATM from 2006-2010 and ranged from 20.07 to 29.92 mm in KEFJ from 2007-2011 (no prey items observed in 2010) (Figure 28).

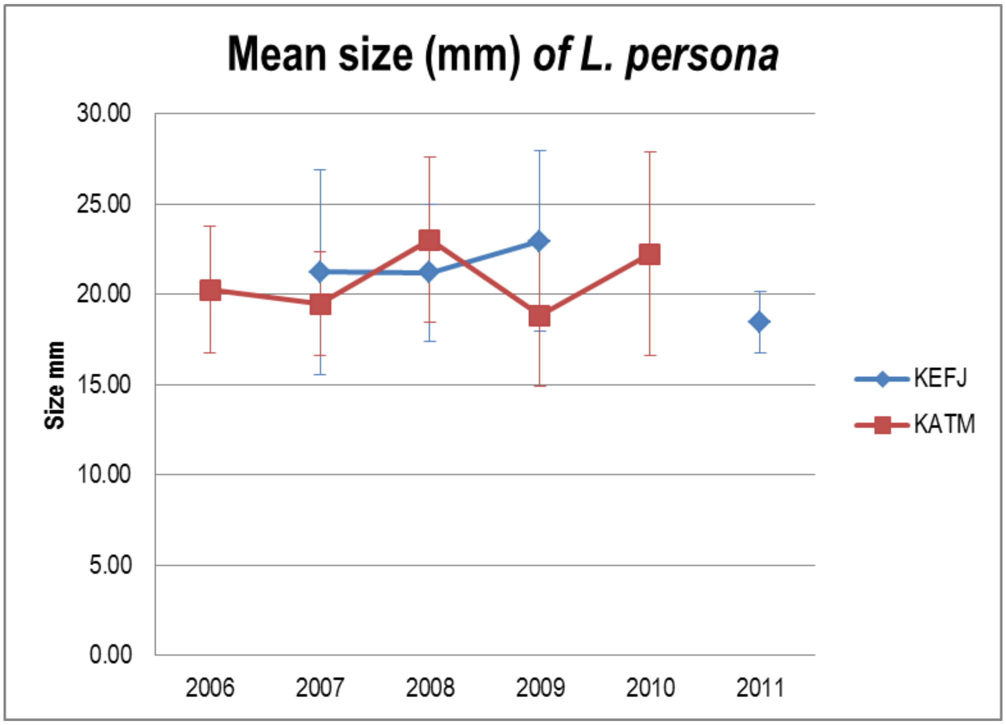

Figure 27. Mean size of *L. persona* from at active black oystercatcher nests in KATM (2006-2010) and KEFJ (2007-2011). No prey items were observed in KEFJ in 2010.

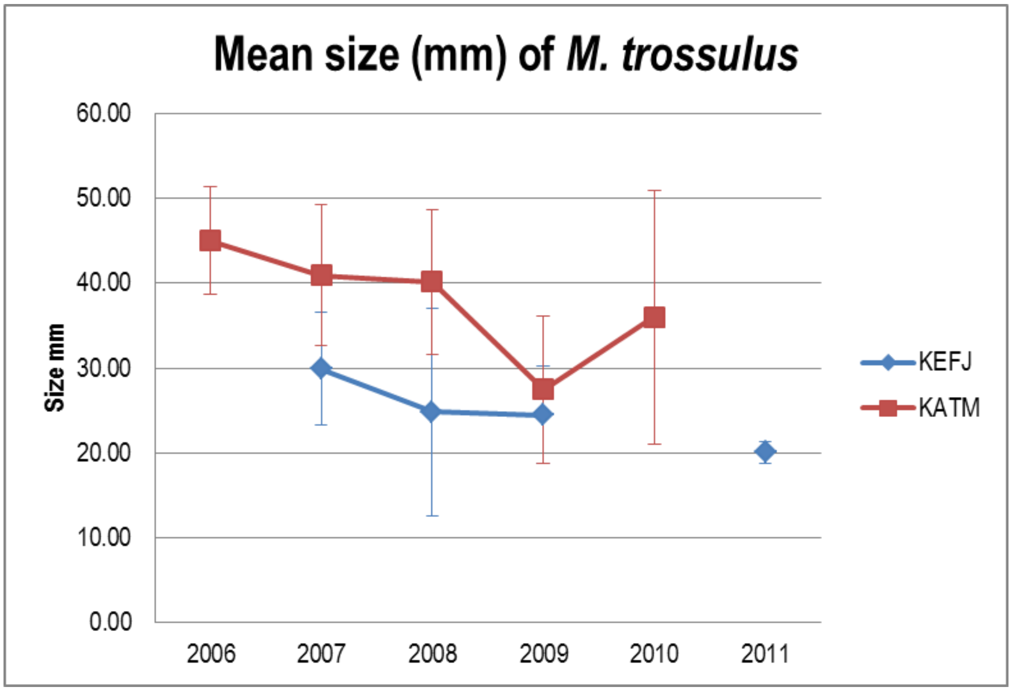

Figure 28. Mean size of *M. trossulus* from active black oystercatcher nests in KATM (2006-2010) and KEFJ (2007-2011). No prey items were observed in KEFJ in 2010.

Discussion

Nest density increased slightly in KEFJ in 2011, but not significantly. Productivity also increased slightly in KEFJ in 2011. Diet proportions and sizes in KEFJ are a reflection of collections at only two nests in 2011. All *M. trossulus* came from one nest and all *L. pelta* came from the other. Because of our limited sample size, the observed decreases in prey sizes should not be considered a park-wide decrease. *M. trossulus* was the dominant prey item collected in KEFJ in 2011. Our data continues to show that black oystercatchers are targeting the larger size classes of mussels and limpets, based on our random sampling in the rocky intertidal and mussel bed sites. Variation in sizes of prey was generally relatively low. This is not surprising, but may be a key metric for monitoring purposes. Measurements of sea otter prey, pre- and post- arrival of sea otters in Glacier Bay, AK, have indicated a decline in prey sizes correlated with the increased occupation of Glacier Bay proper with sea otters (Bodkin et al. 2007a and c). A similar result may possibly occur as densities in nesting black oystercatchers changes. Lower densities of black oystercatchers may lead to increased densities of larger size classes of mussels and limpets sampled at the rocky intertidal sites and mussel beds or nest sites. The reverse may also be possible. Increased black oystercatcher densities may decrease the densities of the larger size classes of prey.

Recommendations

Surveys of black oystercatcher abundance, nest density, and diet as reflected through prey remains brought to provision chicks have been successfully implemented in KATM and KEFJ and have shown that at appropriate spatial scales of analysis, our data should continue to be collected with little revision. Sampling at the current intensity should allow us to detect trends in changes of nest density, productivity and diet (especially prey size) of the black oystercatcher. It appears as though breeding pairs may have multiple nests at a nest site and care should continue to be taken to recognize these as comprising the same nest site. It will be important to conduct future surveys as close as possible in time to these initial surveys and care must continue to be taken to minimize the disturbance to nests during sampling.

Sea Otter

Introduction

Sea otters (*Enhydra lutris*) are a common, conspicuous, and important component of the nearshore trophic food web throughout the North Pacific. They occupy all types of nearshore habitats from sheltered bays, estuaries, and fjords to exposed rocky coastlines (Kenyon 1969), but are constrained by their diving ability to habitats shallower than 100 m depth (Bodkin et al. 2004) and a near exclusive dietary reliance on benthic invertebrate prey (Riedman and Estes 1990). As a consequence of their nearshore distribution and relatively small home ranges, a rich literature exists on the biology, behavior, and ecology of the species. The sea otter provides one of the best documented examples of top-down forcing effects on the structure and function of nearshore marine ecosystems in the North Pacific Ocean (Kenyon 1969, VanBlaricom and Estes 1988, Riedman and Estes 1990, Estes and Duggins 1995) and are widely regarded as a "keystone" species in coastal marine ecosystems (Power et al. 1996). They cause well described top-down cascading effects on community structure by altering abundance of prey (e.g. sea urchins) which can in turn alter abundance of lower trophic levels (e.g. kelps). Sea otters generally have smaller home ranges than other marine mammals, eat large amounts of food, are susceptible to contaminants such as those related to oil spills, and have broad appeal to the public. From the mid-1980s through 2005 declines in sea otters have been observed in the Aleutian Islands (Doroff et al. 2003, Estes et al. 2005, Burn and Doroff 2005). As a result, the Western Alaska stock of sea otters, which occurs from Cook Inlet to the Western Aleutian Islands, which includes KATM as well as Aniakchak National Monument and Preserve, was federally listed in September 2005 as threatened.

For the reasons outlined above, several metrics related to sea otters are incorporated under this vital sign. They include: observations of sea otter foraging, carcass collections to evaluate the age structure of the dying population, and aerial surveys to estimate population abundance. Because sea otters occupy areas outside the nearshore zone, aerial surveys are conducted to increase the accuracy of abundance estimates (Bodkin and Udevitz 1999).

Sea otter population abundance and trends are frequently influenced by the type and quantity of available prey (Kenyon 1969, Monson et al. 2000). Observations of foraging sea otters provide information on food habits, foraging success, (mean proportion of feeding dives that are successful) and efficiency (mean kcal/dive) based on prey numbers, types and sizes obtained by feeding animals. Because sea otter populations are often prey limited, data on foraging behavior will be useful in evaluating potential causes for differences in sea otter densities or trends among regions or years (Estes et al. 1982, 2003b, Gelatt et al. 2002, Dean et al. 2002, Bodkin et al. 2002, Tinker et al. 2008).

Due to high spatial variability in marine invertebrate populations (e.g. extreme patchiness) and difficulty in sampling underwater prey populations, foraging sea otters provide an alternative method to direct sampling of subtidal invertebrates. Following a successful foraging dive, sea otters return to the surface to consume their prey. This provides the opportunity to identify, enumerate, and estimate the size of the benthic organisms they consume. Therefore sea otter foraging observations will provide data on species composition and sizes of subtidal invertebrate prey populations that are difficult to obtain directly. Observations collected over time may allow inference to changes in the species composition and sizes of the nearshore benthic invertebrate communities.

As a result of their nearshore distribution and relatively high density, moribund sea otters often haul out ashore, or their carcasses drift onto beaches. Annual collections of sea otter carcasses provide a record of the ages of dying individuals through analysis of dentin deposition in teeth (Bodkin et al. 1997). The age distributions of dying sea otters generated from annual carcass collections can provide a baseline against which future distributions can be compared and potentially provide inference regarding causes for change in population abundance , behavior, or diet (Monson et al. 2000, Estes et al. 2003a). Combined with data from a fresh carcass stranding program or annual population surveys, age-specific mortality data modeling can be used to inform managers regarding conservation decisions related to causes of mortality (Gerber et al. 2004, Tinker et al. 2006).

Methods

Prey composition, foraging success rate, and prey size were obtained from shore based observations of randomly selected foraging otters. Shore-based observations limited data collection to sea otters feeding within approximately 1 km of shore. High powered telescopes (Questar Corp., Hew Hope, PA.) and 10X binoculars were used to record prey type, number, and size class during foraging bouts of focal animals. A bout consisted of observations of repeated dives for a focal animal while it remains in view and continues to forage (Calkins 1978). Assuming each foraging bout records the feeding activity of a unique individual, bouts were considered independent while dives within bouts were not. Thus the length of any one foraging bout was limited to 20 dives, or one hour, after which a new focal animal was chosen. Within each bout sampled the following metadata were recorded: date, start and end time, age class, sex, reproductive status of the individual and location coordinates. Foraging data collected include dive and inter-dive times, success, prey species, number and size, and if prey were given or taken (typically given to a pup, or taken by a con-specific). The sampling design included the acquisition of foraging data within a 10 km radius of each of the five established rocky intertidal invertebrate and algal sites. The objective was to annually obtain data from 10 individuals within each of these 10 km buffers, a total of 50 bouts per year.

Sea otters in the study areas were generally not individually identifiable. In addition, some foraging areas may have been used more than others by individuals and by otters living in the area in general. Therefore individual sea otters may have been observed more than once leading to potential bias toward individuals sampled more than once. To minimize this potential, observers use characteristics such as sex, sizes, coloration, and reproductive status to identify individuals. If more than one animal was observed foraging, selection was based on proximity, alternating between closest and furthest.

Throughout the study areas in KATM and KEFJ, we have identified segments of shoreline or offshore islands to search for sea otter carcasses. These areas have been consistently searched by two or more observers. Search patterns cover from the storm strand line to the water’s edge and focus on areas where larger amounts of debris collect. When a carcass is encountered the skull and baculum, if present, are collected. The following data are recorded: date, observers, condition of carcass, parts collected, latitude/longitude, location on beach (e.g. strand line, above high tide, etc.), and cause of mortality (usually not known). A premolar tooth (or substitute if the premolar is not available) is sent to Matson's Laboratory in Montana for cementum layer age analysis.

Of the various metrics measured in regard to the sea otter vital sign, only foraging observations and carcass collections have been collected in KATM since 2006 and KEFJ since 2007. Here we will be reporting only on the descriptive analyses associated with data acquired directly from observations of foraging sea otters and age-specific mortality. Results from aerial surveys conducted in KATM in 2008 and in KEFJ in 2007 and 2010 are reported elsewhere (Bodkin et al 2008, Coletti et al. 2009 and 2011a).

One of the objectives for this monitoring program is to detect levels of change deemed ecologically important (Dean and Bodkin 2011a). For the sea otter foraging data we have established a 0.35 change in the proportion of dominant prey categories, a 0.50 change in prey size and a 0.20 increase or 0.33 decrease in the number of hours needed to meet energetic requirements as ecologically relevant changes to detect. Programming capable of providing variance estimates of energy recovery rates is presently in revision, precluding power analysis for this metric. Power analysis for liner regression (Gerrodette 1993) was used to evaluate levels of change in focal species densities that could be detected over time. Forage data are analyzed at the spatial scale of a park. Future analyses may include finer spatial resolution analyses as sample sizes increase within each of the five buffers associated with the intertidal sites and should include caloric recovery rate power analyses.

Results

We did not collect foraging data in KATM in 2011 but some summaries from 2006-2010 are presented here. In KEFJ in 2011 we observed 54 independent feeding bouts comprised of approximately 500 dives (Table 3). During five field seasons (2006-2010) at KATM we obtained data from 242 independent sea otter foraging bouts, consisting of 2,290 dives (Table 3). The prey recovery success rate was 89% for dives with known outcomes (range 87% - 92%) (Figure 31). During five field seasons (2007-2011) at KEFJ we obtained data from 250 independent sea otter foraging bouts, consisting of 2,210 dives (Table 3). The prey recovery success rate was 87% for dives with known outcomes (range 68% - 96%) (Figure 31).

Table 3. Summary of sea otter foraging observations in KATM and KEFJ from nearshore monitoring data collection, 2006 - 2011. A bout is the sampling unit for data analysis**.**

Year	Number of bouts observed		Number of dives observed		Mean number of observed dives per bout		St. error number of dives per bout	
	KATM	KEFJ	KATM	KEFJ	KATM	KEFJ	KATM	KEFJ
2006	65	.	451	.	6.74	.	0.24	.
2007	54	45	498	471	7.66	8.89	0.24	0.31
2008	38	57	427	392	8.57	5.73	0.28	0.23
2009	36	37	392	269	8.43	7.16	0.29	0.34
2010	49	57	522	497	7.71	6.97	0.23	0.25
2011	.	54	.	581	.	8.28	.	0.23
All Years	242	250	2,290	2,210	7.82	7.26	0.1	0.12

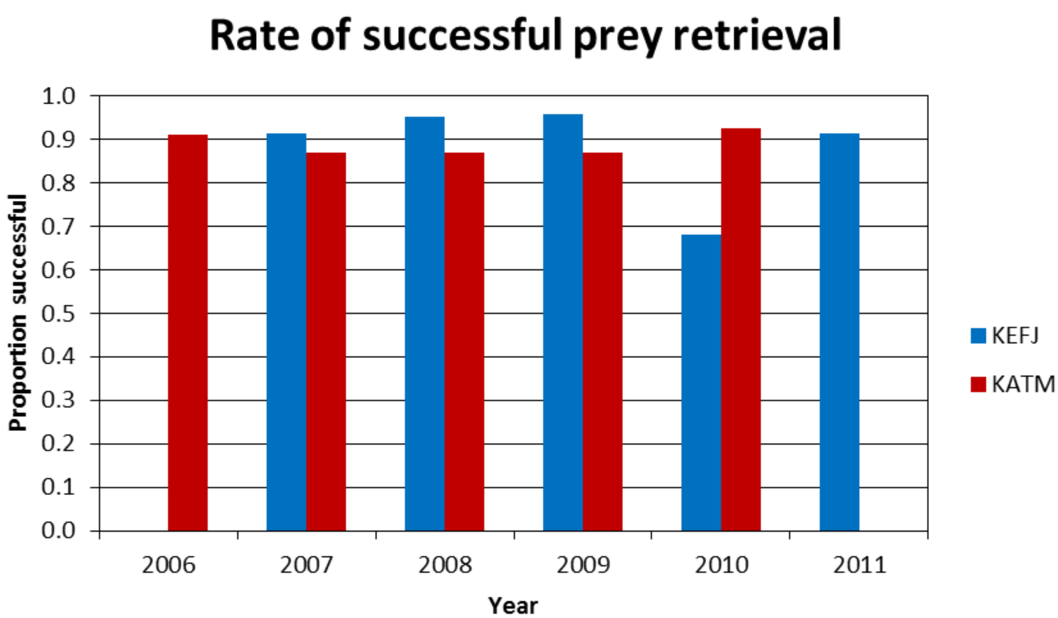

Figure 29. Success rate equals the proportion of known outcome dives where prey was successfully retrieved (Yes) by foraging sea otters in KATM 2006-2010 and KEFJ, 2007-2011. Dives in which otters were retrieving a previously collected prey item that had been dropped were not included. Additionally, a dive is only counted towards the success rate once, even if more than 1 item was retrieved.

Since 2006, we have observed sea otters feeding on almost 40 different prey items including bivalves, decapod crustaceans, gastropods, and echinoderms (Table 4). At KATM, clams dominated sea otter diets across all years of data collection, comprising greater than 60% of the diet. In 2006 octopus accounted for 12% of identified prey, in 2008 chitons were 16%, and in 2009 snails and urchins accounted for 30% and 14%, respectively. Otherwise, chitons, crabs, mussels, octopus, snails, sea stars, sea urchins, and other prey each comprised less than 10% of the of prey recovered (Coletti et al. 2011b). At KEFJ, mussels (*Mytilus trossulus*) dominated sea otter diets across all years of data collection, comprising about 61% of the diet (Figure 30). In all years, clams were the second most prominent prey item comprising about 25% of the diet. Otherwise, chitons, crabs, octopus, snails, sea stars, sea urchins, and other prey each comprised less than 10% of the of prey recovered. Annually there has been little observed change in the predominant prey category at either Park.

Table 4. List of prey items that sea otters were observed consuming in KATM and KEFJ, 2006 - 2011.

Phylum (Subphylum)	**Class (Order)**	**Prey Item (Genus, species)**
Mollusca	Polyplacaphora	*Cryptochiton stelleri*, *Katharina tunicata*
	Gastropod	*Neptunea* spp., *Nucella* spp., *Fusitriton* sp.
	Bivalvia	*Macoma nasuta*, *M* spp., *Mya truncata*, *M* spp., *Leukoma staminea*, *Saxidomus gigantea*, *Serripes sp.*, *Clinocardium nutallii*, *Modiolus modiolus*, *Mytilus Trossulus*, *Pododesmus macroschisma*, *Chlamys* spp., *Tresus capax*
	Cephalopoda	*Octopus dofleini*
Echiura		*Echiurus* spp.
Arthropoda (Crustacea)		
	Cirripedia	barnacles
	(Decapoda)	*Cancer* spp., *Telmessus cheiragonus*, *Pagurus* spp.
Echinodermata		
	Asteroidea	*Solaster* spp., *Pisaster* spp., *Pycnopodia helianthoides*, *Evasterias* sp.
	Ophiuroidea	*Ophiurid* spp.
	Echinoidea	*Strongylocentrotus droebachiensis*, *S. franciscanus*, *S. purpuratus*, *Dendraster excentricus*
	Holothuroidea	*Cucumaria fallax*, *Parastichopus* sp.
Chordata		
	Chondrichthyes	skate egg case
	Osteichthyes	*Ammodytes* sp. (sand lance), various fish

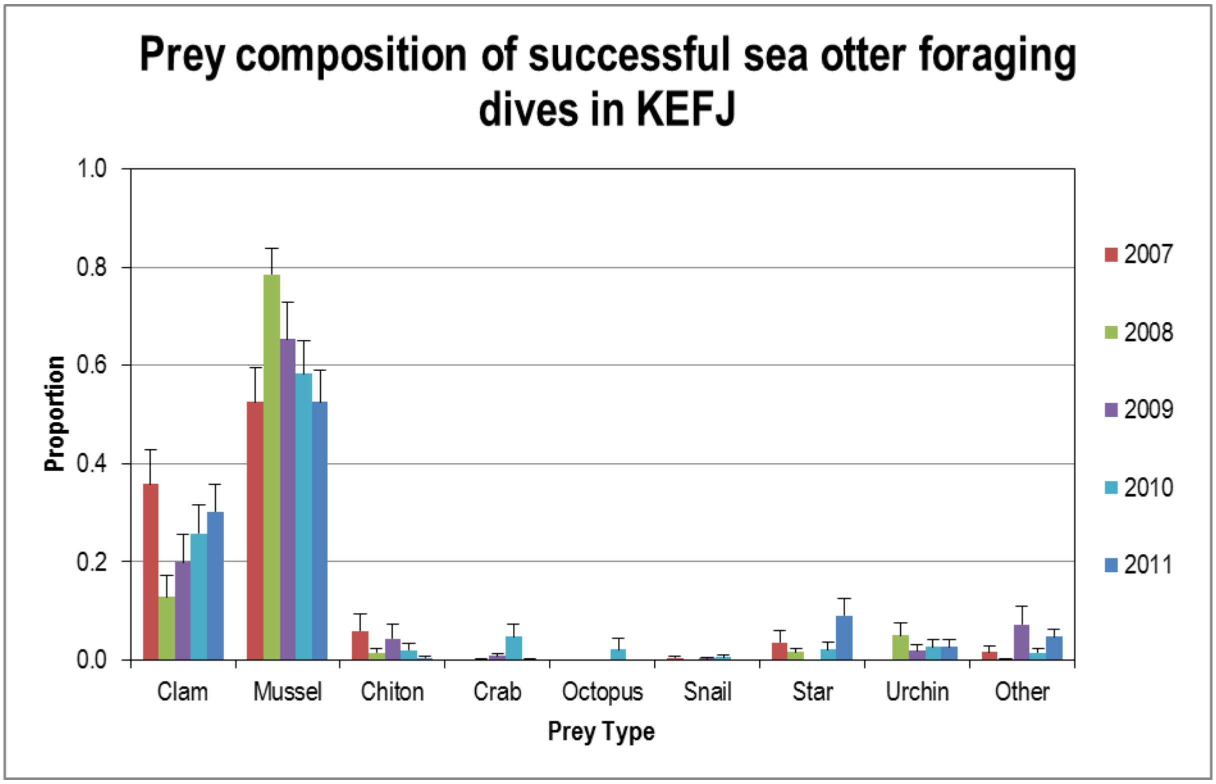

Figure 30. Proportion of identified prey retrieved by foraging sea otters in KEFJ from 2007 through 2011. Unidentified prey items are not included in these calculations. The “Other” category includes items such as worms, fish, egg cases and other infrequently consumed prey. Additionally, a prey item is only counted towards the proportion once, even if more than 1 of the same item was retrieved on the same dive. Error bars represent standard error.

Sizes of prey captured by foraging sea otters vary by species at KEFJ (Figure 31). The predominant prey, mussels, averaged ~24 mm over all sites and all years combined, and this size was consistent across years. Clams averaged ~50 mm and unidentified prey items were ~26 mm.

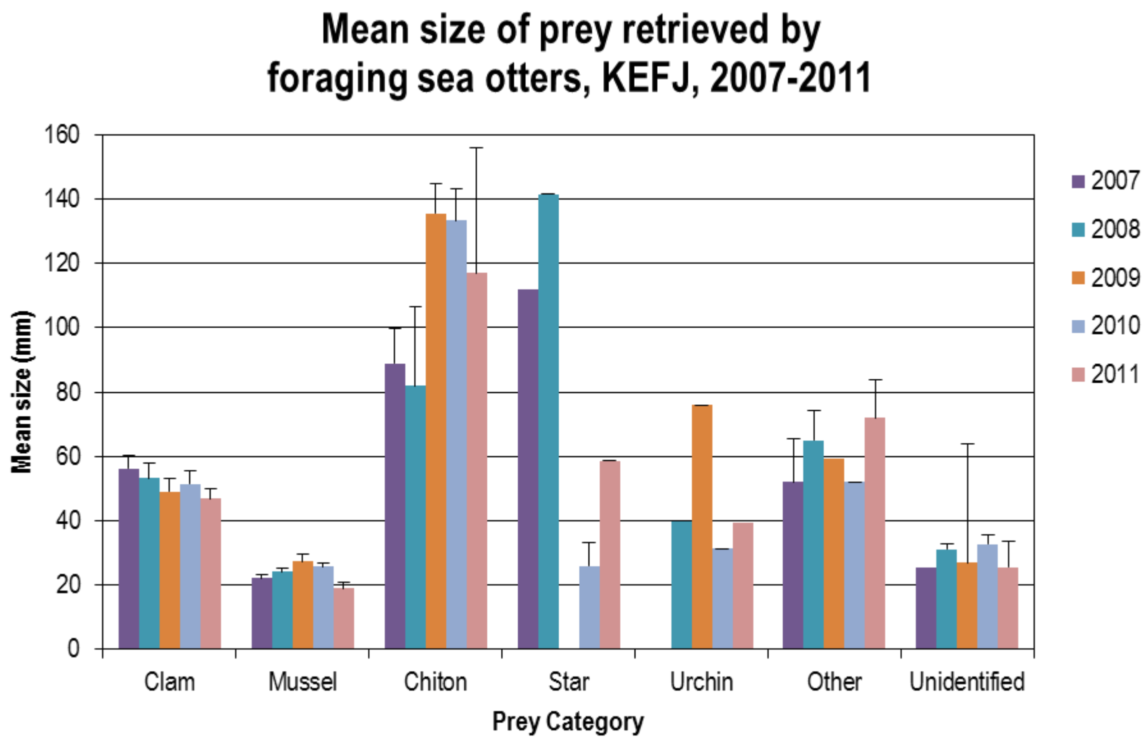

Figure 31. Mean size of prey items recovered by prey category by foraging sea otters in KEFJ (2007-2011) by year. Sizes from all prey items retrieved were used in the calculations. Error bars represent standard errors. Several prey categories were excluded due to low numbers retrieved or unknown sizes.

We did not recover carcasses in KATM in 2011 and not enough were found in KEFJ to warrant analysis at this point.

Discussion

Using the methods briefly described above, we were able to estimate sea otter foraging success, prey composition, mean prey size, and age-specific mortality. Predominant prey varied between parks, but within each park was consistent over time. We anticipate that further development of the model to analyze rates of energy recovery will allow us to detect ecologically meaningful levels of change in the future. Foraging success rates were similar across years and between parks, except for the low rate in KEFJ in 2010. This appears to be due to the inclusion of a higher than typical number of bouts from juvenile otters. Juveniles are hypothesized to be still acquiring the necessary skills for successful independent foraging and have been observed in other areas to have lower success rates than adults. Subsequent analyses will account for age class. Overall a wide range of prey items was observed in both parks. Sea otters display individual preferences in prey selection that can be attributed to prey availability, maternally derived learning and likely several other factors. Since this monitoring protocol has no plans for marking and following individual sea otters' dietary preferences, our analyses will focus on population-level metrics that can be compared over time and to other populations. In KATM, the primary prey category across years is clams, while in KEFJ, mussels predominate. Unidentified prey is a large component of the diet in both parks. Our developing forage model addresses the unidentified prey component by resampling the known items weighting for other known metrics such as retrieval time, consumption time, and size. Analyses are underway to determine if our methods will allow detection of the levels of change deemed ecologically important. Power analyses from past sea otter studies indicate that we will be able to do so. In the course of collecting the observations we have determined the need to address larger prey items such as octopus and fish. Our methods allow us to estimate the size of a prey item by comparing the item to the otter's paw width. In other research, otter paws have been measured yielding a mean otter paw width of 52 mm. This method is successfully employed by sea otter researchers throughout the sea otter range; however it is proving difficult to adapt to extremely large items that exceed 4 paw widths. We are working to develop alternate methods of sizing these items and there is already a mechanism to include them in the forage data model.

Searches for sea otter carcasses continue in KEFJ and KATM. To date, we have not recovered sufficient carcasses from KEFJ to employ age-specific mortality analyses. Discussions are underway to determine ways to improve our carcass recoveries in KEFJ such as adding areas of shoreline to search or searching more frequently to recover carcasses prior to removal by scavengers.

Recommendations

Based on these results, we recommend continued collection of sea otter foraging data with an emphasis on completing the analysis model. Additionally, 50 bouts should be set as the minimum target. Results should be viewed both longitudinally and within the larger framework of known otter foraging studies for context. Sea otter carcass collections should also be continued and the expansion of collection efforts should be seriously considered for both parks. It will be important to build an analysis model that facilitates the inclusion of additional data over time to recognize emerging trends.

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